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THIRD BIENNIAL REPORT

OF THE

State Water Commission of California

1919-1920

CALIFORNIA STATE PRINTING OFFICE
SACRAMENTO, 1921

8089

PLATE I

Kerchkoff Dam on San Joaquin River diverting water through several miles of granite tunnel for development of hydro-electric power.

TC
424

LETTER OF TRANSMITTAL.

SAN FRANCISCO, CALIFORNIA.

To His Excellency, THE GOVERNOR,
State of California.

SIR: We have the honor to herewith submit a report of work of this Commission under the terms of the Water Commission Act as amended in 1917. This report covers a period from September 1, 1918, to September 1, 1920.

Respectfully submitted this twentieth day of December, 1920.

STATE WATER COMMISSION,

CHARLES H. LEE, *President.*

JOSEPHINE A. PATTEN, *Secretary.*

STATE WATER COMMISSION

WILLIAM D. STEPHENS, GOVERNOR (*ex officio*)------Sacramento, California

W. F. McCLURE, STATE ENGINEER (*ex officio*)----------Sacramento, California

CHARLES H. LEE, PRESIDENT----------Berkeley, California

W. A. JOHNSTONE----------San Dimas, California

A. W. MASON----------Bakersfield, California

CONTENTS.

CHAPTER I.

Page

INTRODUCTION ---- 9
Purpose ---- 9
Progress During Biennial Period ---- 9
Future Work of the Commission ---- 12
Recommendations ---- 15

CHAPTER II.

SUPERVISION OF APPROPRIATION OF WATER ---- 16
Growing Importance ---- 16
Waters Included Under the Act ---- 17
Character of Supervision ---- 17
Administrative Routine ---- 19
Statistical Summary of Applications ---- 21
Agricultural Applications ---- 23
Power Applications ---- 27
Mining Applications ---- 29
Municipal Applications ---- 29
Permits Issued ---- 29
Relation Between Power and Irrigation ---- 30
Summary ---- 33

CHAPTER III.

ADJUDICATIONS AND REFERENCES ---- 34
Determination of Water Rights by the Courts and by the State Water Commission ---- 34
Adjudications ---- 37
Stanislaus River Adjudication ---- 37
West Carson River ---- 38
References ---- 38
Niles Cone ---- 38
North Fork of Cottonwood Creek in Shasta County ---- 39
San Pedro Creek ---- 40
Hat Creek ---- 40
Red Rock Creek ---- 41
Willow Creek ---- 41

CHAPTER IV.

DISTRIBUTION OF WATER FROM NATURAL STREAMS ---- 42
Water Master Service ---- 42
Recent Experience in California ---- 43
Experience of Other States ---- 45
Proposed Legislation ---- 47

CHAPTER V.

ARBITRATIONS ---- 48
San Diego River ---- 48
Bishop Creek ---- 48

CHAPTER VI.

Page

SPECIAL INVESTIGATIONS ---- 49
Kings River ---- 49
Kern River ---- 49
San Joaquin River ---- 50
Inyokern Irrigation District ---- 50
Salinity Investigations in the Delta of the Sacramento and San Joaquin Rivers 51
Land Settlement Board ---- 52
Water Supply for State Institutions ---- 52

CHAPTER VII.

COOPERATIVE WORK ---- 53
United States Geological Survey ---- 53
Los Angeles County and Santa Ana River Studies ---- 55
San Diego River ---- 56
Emergency Water Conservation Conference ---- 56
United States Department of Agriculture, Bureau of Public Roads ---- 57
Duty of Water in Rice Culture ---- 57
Use of Water from Kings River ---- 57
New Irrigation Map ---- 58
State Department of Engineering ---- 58
Kaweah and Tule River Investigations ---- 59

CHAPTER VIII.

FEES AND ADMINISTRATIVE COST ---- 60
Applications to Appropriate Water ---- 60
Adjudications ---- 61

CHAPTER IX.

IRRIGATION ACT DISTRICTS ---- 63

CHAPTER X.

IRRIGATION DISTRICTS OF CALIFORNIA ---- 65

CHAPTER XI.

RICE CULTURE ---- 71

CHAPTER XII.

USE OF WATER FROM KINGS RIVER ---- 75

APPENDICES.

APPENDIX A.

FINANCIAL STATEMENTS ---- 79

APPENDIX B.

WORK OF LEGAL DEPARTMENT. By L. D. BOHNETT, *Attorney* ---- 80

APPENDIX C.

INVESTIGATIONS ON KERN RIVER IN 1920 ---- 83

APPENDIX D.

SALINITY INVESTIGATIONS IN THE SACRAMENTO AND SAN JOAQUIN DELTA ---- 85

APPENDIX E.

ENGINEERING INVESTIGATION OF PERCOLATION FROM ALAMEDA CREEK AND GROUND WATER STUDIES ON NILES CONE. By PAUL BAILEY, *Hydraulic Engineer* ---- 95

APPENDIX F. Page

FINAL DETERMINATION IN THE CONTROVERSY BETWEEN ALAMEDA WATER DISTRICT AND SPRING VALLEY WATER COMPANY REGARDING THE WATERS OF ALAMEDA CREEK---------- 107

APPENDIX G.

WORK OF STATE WATER COMMISSION ON KINGS RIVER---------- 133

APPENDIX H.

PROGRESS REPORT ON SAN JOAQUIN HYDROGRAPHIC SURVEY------- 141

APPENDIX I.

REPORT TO THE STATE WATER COMMISSION ON THE PROGRESS OF THE COOPERATIVE SURFACE WATER INVESTIGATIONS IN CALIFORNIA BY THE WATER RESOURCES BRANCH OF THE UNITED STATES GEOLOGICAL SURVEY FOR 1919-1920---------- 146

APPENDIX J.

EMERGENCY WATER CONSERVATION CONFERENCE---------- 152

APPENDIX K.

COLUSA BASIN ---------- 156

APPENDIX L.

THE COLORADO RIVER. By W. A. JOHNSTONE, *Commissioner*---------- 159

APPENDIX M.

PROSOSED WATER MASTER BILL---------- 162

TABLES.

1. Summary of Applications During Biennial Periods---------- 21
2. Greater Size of Projects Under Applications During Past Two Years as Indicated by Ratios of Acreage and Horsepower per Application-------- 23
3. List of Important Proposed Irrigation Projects as Indicated by Applications to Appropriate Water Filed During the Biennial Period Ending September 1, 1920----------164-168
4. List of Important Proposed Hydroelectric Power Projects as Indicated by Applications to Appropriate Water Filed During the Biennial Period Ending September 1, 1920----------169-171
5. List of Important Proposed Mining Developments as Indicated by Applications to Appropriate Water Filed During the Biennial Period Ending September 1, 1920---------- 172
6. List of Important Proposed Municipal Projects as Indicated by Applications to Appropriate Water Filed With the State Water Commission in the Biennial Period Ending September 1, 1920---------- 173
7. List of Important Permits to Appropriate Water Issued During the Biennial Period Ending September 1, 1920---------- 174
8. Relative Importance of Present and Proposed Power and Irrigation Development on Certain Important Streams of California---------- 176
9. Water Codes in Irrigation States---------- 45
10. Irrigation Districts Having Applications for Appropriation of Water on File With the State Water Commission---------- 66-70
11. Growth of Rice Industry in California---------- 71
12. Summary of Measurements of Duty of Water in Rice Irrigation in the Sacramento Valley ---------- 73
13. Summary of Kings River Canal Diversions---------- 140
14. List of Current Meter Measurements on Canals Diverting From San Joaquin River ---------- 144

ILLUSTRATIONS.

DIAGRAMS.

		Page
Diagram 1.	Number of Applications to Appropriate Water Received Monthly Since Organization of the Commission	22
Diagram 2.	Total Area of Lands Proposed to Be Irrigated Under Applications to Appropriate Water Which Have Been Received Since November, 1914	24
Diagram 3.	Total Proposed Theoretical Horsepower to Be Developed Under Applications to Appropriate Water Which Have Been Received Since January 1915	26
Diagram 4.	Sketch Map of Sacramento and San Joaquin Delta With Reference to Salinity Investigations, 1920	86
Diagram 5.	Relation of Salinity in Sacramento Delta to River Discharge at Sacramento, 1920	87
Diagram 6.	Advance and Retreat of Salinity in Sacramento Delta	88
Diagram 7.	Relation of Salinity in San Joaquin Delta to River Discharge at Lathrop, 1920	89
Diagram 8.	Advance and Retreat of Salinity in San Joaquin Delta, 1920	90
Diagram 9.	Variation of Salinity With Tide at H Street Wharf, Antioch	91
Diagram	Sketch map of Niles Cone and Alameda Creek Watershed	96
Diagrams 10a and 10b.	Showing Maximum Mean Daily Rate of Percolation Between Upper and Lower Gaging Stations at a Mean Daily Temperature of 50 Degrees, Fahrenheit	110 and 112
Diagram 11.	Showing Rate of Change in Percent of Maximum Mean Daily Percolation With the Mean Daily Rate of Percolation Between Upper and Lower Gaging Stations at a Mean Daily Temperature of 50 Degrees Fahrenheit	114
Diagram 12.	Canals and Ditches Diverting Water From Kings River	132

PLATES.

Plate	I.	Kerckhoff Dam on San Joaquin River Diverting Water Through Several Miles of Granite Tunnel for Development of Hydro-Electric Power	Frontispiece
Plate	II.	Pumping Plant on Sacramento River Supplying Water for Irrition of Conaway Ranch	10
Plate	III.	Wilkins Slough Pumping Plant on Sacramento River Supplying Water for Irrigation of Lands in Reclamation District No. 108	14
Plate	IV.	Pumphouse and Discharge Pipes of Sutter Basin Company Pumping Plant	18
Plate	V.	Hillside Orchard Irrigation	18
Plate	VI.	San Pablo Dam and Reservoir Under Construction by East Bay Water Company for Municipal Supply of East Bay Cities	28
Plate	VII.	Kerckhoff Power House on San Joaquin Where Water Is Returned to the Stream After Generation of 50,000 Horsepower of Electric Power	32
Plate	VIII.	Gaging Stations on Santa Ana Drainage	54
Plate	IX.	Eagle Lake, the Proposed Source of Supply for the Baxter Creek and Tule Irrigation Districts	62
Plate	X.	Musselbeck Dam Constructed by Happy Valley Irrigation District	64
Plate	XI.	Site of Proposed Don Pedro Dam on Tuolumne River to Be Constructed by Modesto and Turlock Irrigation District for Storage of 300,000 Acre-Feet of Water Annually	64
Plate	XII.	Rice Irrigation in Sacramento Valley at First Flooding	72
Plate	XIII.	Rice Irrigation in Sacramento Valley Just Before Final Flooding	72
Plate	XIV.	Upper Measuring Station on Alameda Creek	94
Plate	XV.	Measuring Alameda Creek by Wading Above the Upper Station	94
Plate	XVI.	Water Stage Register at Well on Niles Cone Recording Fluctuations of Level of Underground Water	100
Plate	XVII.	Current Meter Reel at Upper Measuring Station on Alameda Creek	108
Plate	XVIII.	Headgate of Peoples Ditch on Kings River at Which Diversions Are Regulated by Water Master Under Supervision of State Water Commission	132
Plate	XIX.	Gaging Stations on Santa Ana Drainage	148
Plate	XX.	Gaging Stations on Santa Ana Drainage	150

REPORT OF STATE WATER COMMISSION.

CHAPTER I.

INTRODUCTION.

Purpose.

The State Water Commission is an administrative and quasi-judicial body having supervision over the acquisition and defining of water rights and the use of water from the natural stream channels and lakes of California.

The Commission was created to carry out the terms of the Water Commission Act passed by the Legislature in 1913, and approved under referendum December 19, 1914. This act provides for a definite record of water right titles and constitutes a code of water law governing the use of surface water and underground water flowing through known and definite channels, based upon rights by appropriation. It is designed to serve three main purposes.

First—To provide a definite system for public supervision of the initiation of water rights acquired subsequent to the adoption of the act and a complete record thereof in a central office.

Second—To provide a procedure whereby all rights to surface water, under appropriation initiated prior to the date the law became effective (December 19, 1914) and usually uncertain in many important elements, such as amount, priority, etc., can be definitely ascertained and recorded.

Third—To provide necessary administrative machinery under which water can be equitably distributed to the various diversion systems entitled to its use, in other words, to provide state supervision of valuable property rights in water were defined and recorded under the laws of the state. This feature of a complete water code is at present incomplete in the Water Commission Act (section 37).

Progress During Past Biennial Period.

The work of the Water Commission during the past two years has increased both in volume and diversity. More permits and licenses to appropriate water have been issued than in any previous biennial period, and more adjudications and court references have been before the Commission. The importance of the water rights now depending upon the Water Commission Act for legality can be appreciated by the

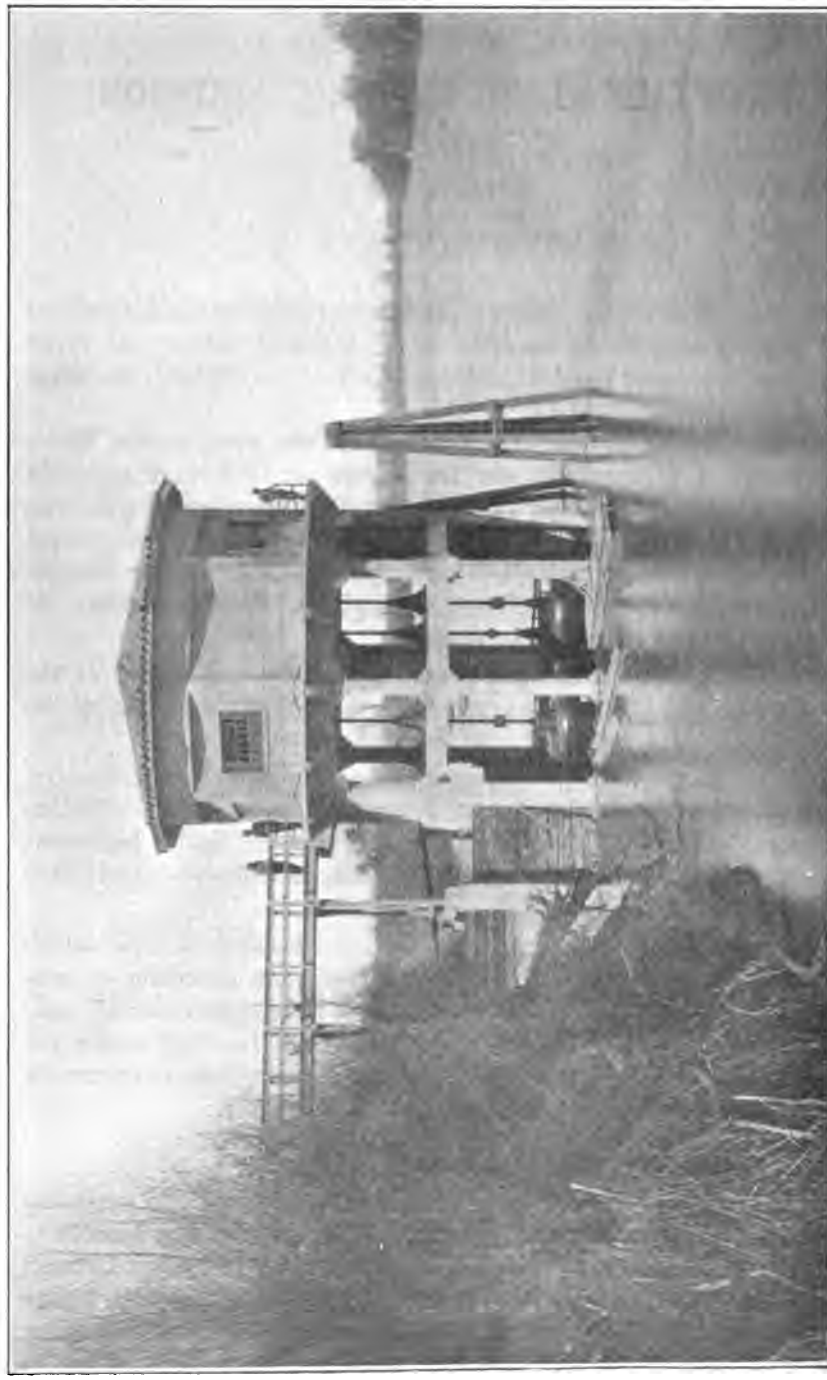


PLATE II.
Pumping plant on Sacramento River supplying water for irrigation of Conaway Ranch.

fact that construction and application of water to use has been completed or is in progress of completion for 618,400 acres of irrigable land and for development of 243,000 horsepower of electrical energy, and that these figures will be more than doubled before the end of 1920.

Activity in the initiation of water development projects since the close of the war has been phenomenal. The acreage and horsepower for which applications to appropriate water have been received by the Commission during the biennial period ending September 1, 1920, considerably exceed the total received during the two preceding biennial periods. The applications now pending, most of which have been received during the past year, seek water for the irrigation of more than 10,000,000 acres and the development of approximately 5,300,000 horsepower of electrical energy. These quantities represent a large proportion of the ultimate irrigable area and electrical development of the state. The increased volume of work before the Commission in connection with the initiation of new water rights is great. An estimate based on applications now on file indicates that it will be at least threefold greater during the coming biennial period than during the two past biennial periods.

In addition to this phase of its work, progress has been made in the practical application of other features of the act. Adjudications of water rights initiated prior to the enactment of the Water Commission Act have been started on two stream systems in accordance with the procedure as amended in 1917, and are well on toward completion. The Stanislaus River adjudication involves vested water rights for an irrigable area of 131,865 acres and for more than 40,000 developed horsepower of electrical energy. The progress to date has been satisfactory and fully corroborates the experience of Oregon and other states as to the effectiveness of the procedure as compared with ordinary court procedure.

The idea of public supervision of canal diversions from natural streams has also been put into effect. At the request of water users on Kings River a water master has been appointed and for the past sixteen months has been distributing water to the various canals diverting from the stream up to the 2000 second-foot stage in accordance with an agreed schedule of priorities. The presence of a disinterested and trained public official on the stream has given a confidence and a feeling of getting a square deal which was never experienced under the old regime of every man for himself, and it is doubtful if the water users would ever consent to a return to the old condition. The plan of operation has been much the same as that followed in other irrigation states, some of which have had a complete system of distribution of water from natural streams by public officials in effect for over thirty years.

A somewhat similar plan was followed by the Emergency Water Conservation Conference this season on the Sacramento River, under a water master appointed from the engineering staff of the Water Commission. These successful examples and the last three dry years will do much to awaken the people of the state to the value of legislation providing for the appointment, when needed, of water masters under the supervision of the Water Commission.

In addition to other activities, the Commission has carried on several general investigations of stream systems and water resources under sections 10 and 40 of the act. Among the latter may be mentioned the systematic measurement of all diversions from Kings and San Joaquin rivers for complete irrigation seasons. Investigational work and stream gauging has also been carried on in cooperation with various state and federal departments.

Future Work of the Commission.

A stage of development of the water resources of the state has now been reached which demands the active application of all the provisions of a complete water code, if orderly and permanent progress is to be made without financial loss and periods of stagnation. The normal summer flow of all the streams of the state, even that of the Sacramento river, has now been fully appropriated and put to use. There is, however, but forty per cent of the irrigable acreage of the state for which water can be provided, which is irrigated at the present time, and but twelve per cent of the ultimate hydro-electric power development has been made. There is at present an insistent demand on almost every stream of the state for water far in excess of the natural summer flow of the streams to provide. On the Sacramento river the demand for irrigation exceeds the late summer supply by 300 per cent, as evidenced by applications on file with the Water Commission. A certain amount of water can be made available by more efficient use of natural stream flow and development of underground waters, but the greater portion of the required additional supply must be developed by construction of storage reservoirs and regulation of stream flow, holding the flood runoff for use during periods of low natural flow. Such regulation is needed both for irrigation and for power. The future work of the Water Commission must be viewed in the light of these water problems now before the people of the state.

Among the problems which the Water Commission Act, with certain amendments, is particularly adapted to solve either in part or in whole, provided funds are available to put its provisions into effect, are the following:

1. Hesitancy of capital to invest in water development projects because of uncertainty as to water rights.

2. Conflict between power and irrigation interests.
3. Regulation of flow from stream-bed reservoirs.
4. Interference of diversions in time of shortage.
5. Lack of stream flow and water resource data.

The working out of a comprehensive plan of development based on surveys, physical data and engineering studies, is not a difficult matter. There are other problems, however, having to do with finance, law and human nature. These problems are the difficult ones and several of those that are listed above are of such a character.

These problems are not of the future, but are upon us now. Well advised capital is already asking not only for a permit to appropriate issued by the Water Commission, but it is asking as to possibility of conflict with other interests, as to the definition of water rights vested before the Water Commission Act went into effect, and as to the probability of getting the water supply to which a permit and license would entitle it, even if all rights were adjudicated. The owners of existing irrigation water rights are already asking how these proposed great power developments will affect them and their use of water. The enthusiastic proponents of large stream-bed reservoir projects are already being asked how storage water can be released into a natural stream with assurance of its escaping illegal diversion before reaching its destination, or how such a reservoir can be operated to the satisfaction of prior and vested rights of down-stream water users. And as for the interference of diversions from natural flow in times of shortage, the experience of the past three years has shown this to be a vital problem on every stream in the state.

The answer to these questions lies in the application of the provisions of a complete water code. Such a code provides: First, for the initiation of new water rights under the supervision of an administrative board having opportunity to eliminate conflict in interests through informal conferences and mutual agreements between contestants; and also having authority to withhold permit to appropriate where unappropriated water does not exist, or where the issuance of permit would be detrimental to public welfare. Second, it provides for the complete, rapid and inexpensive adjudication of water rights on stream systems by an administrative body in advance of dispute and litigation. Third, it provides for the accurate and fair distribution of water from natural streams by public officials, in accordance with defined and adjudicated water rights. With such a code in effect, Oregon has overcome the hesitancy of capital to invest; has largely eliminated the potential conflict between power and irrigation interests; has made possible the operation of stream-bed reservoirs without injury to prior and vested

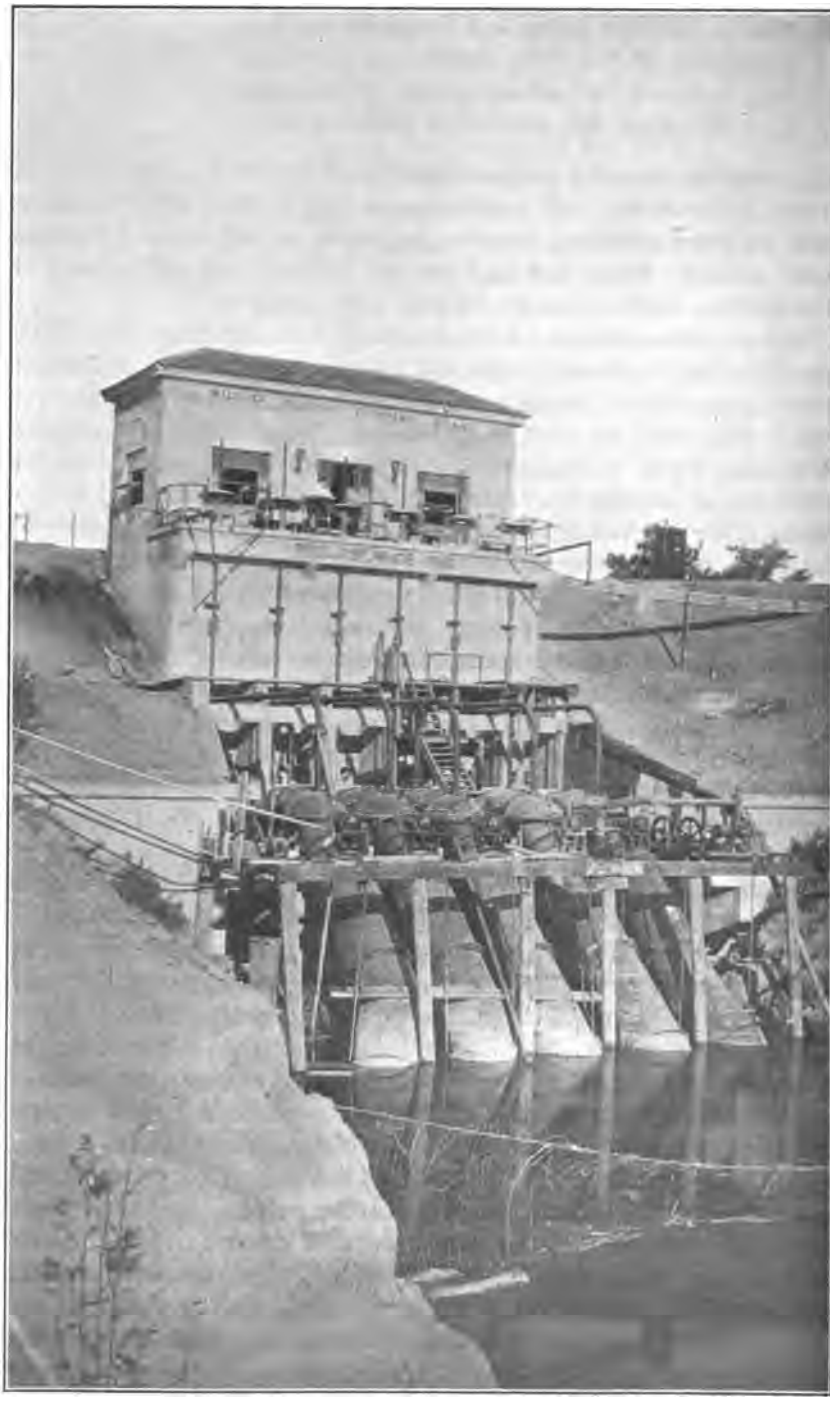


PLATE III.

Wilkins Slough pumping plant on Sacramento River supplying water for irrigation of lands in Reclamation District No. 108.

water rights or loss of storage water by illegal diversion; and has solved the problem of interference of diversions in times of shortage.

The California Water Commission Act lacks as yet one feature of a complete water code, namely, detailed provisions for public supervision of the distribution of water from natural streams. The California Water Commission has also never had sufficient funds to actively undertake stream adjudications. In fact, with the recent rapid increase in receipt of applications for appropriation it has had insufficient funds even for this phase of its work.

With certain amendments, however, and funds to put its provisions into effect, the California Water Commission Act should be equally as effective as the Oregon statute. The time to make it effective is now. To delay means the promotion of ill-advised projects and the turning of conservative capital and enterprise to other fields. Water resources are the foundation of California's wealth and such a catastrophe should not be invited.

Recommendations.

1. Legislation amending section 37 of the Water Commission Act so as to provide machinery for the public supervision of distribution of water from natural streams and lakes in accordance with defined water rights, and the appointment of water masters when needed.

2. Appropriation of sufficient funds by the legislature to enable the Water Commission to more effectively carry out the provisions of the act.

3. Appropriation of funds to enable the Commission to carry on additional stream gaging measurements and water resource investigations necessary to bring about the fullest use of the water resources of the state, in the public interest.

CHAPTER II.

SUPERVISION OF APPROPRIATION OF WATER.

Growing Importance.

Thus far in its history, the largest part of the work of the Commission has been the supervision of the initiation of new water rights based upon appropriation and beneficial use. The latter includes irrigation, development of hydro-electric energy, mining and municipal uses. The importance of the interests depending and definitely proposing to depend upon the provisions of the act for water right titles, is indicated by the following tabulation of data as of date September 1, 1920:

Estimated area possible to be irrigated in California	9,699,600 acres
Area for which agricultural applications for water rights have been received	10,890,000 acres
Area for which agricultural permits for water rights have been issued	618,400 acres
Estimated possible water power development in California	9,250,000 horsepower
Water power for which applications for water rights have been received	5,590,000 horsepower
Water power for which permits for water rights have been issued	243,000 horsepower

More and more is it becoming the rule that financial houses require a showing of water right permit issued by the State Water Commission before lending money on new irrigation or power projects. There is beginning to be general recognition of the value of a definite water right title based upon permit acquired under the provisions of the Water Commission Act. This is true not only among users of water upon nonriparian lands, but includes an increasing proportion of riparian land owners. The latter are beginning to realize that a riparian right merely entitles the owner to a reasonable use in common with all other riparian owners, and that the amount of water to which they are entitled is indefinite and subject to many uncertainties, depending not alone upon variations in the flow of the stream, but also upon the number of riparian owners who may be exercising their rights, as well as numerous other changing conditions in land titles and flow uses. The right by appropriation and beneficial use, on the other hand, entitles the owner to a definite amount so long as there is sufficient water in the stream to supply appropriators with senior priorities.

Waters Included Under Act.

Section 11 of the Water Commission Act defines unappropriated water, and declares that all unappropriated waters are subject to appropriation under the terms of the act. It is under this section that most of the work of the Commission in supervising appropriations originates. Since the organization of the Commission there have been received 1979 applications under this section.

Section 12 provides that upon application of an appropriator of water under an appropriation made and maintained according to the law prior to the passage of the act, the State Water Commission may prescribe a time within which the full amount of water appropriated shall be applied to use, providing the appropriator has exercised due diligence in carrying on the necessary work. This section allows a bonafide appropriator, who has not fully completed his works or put his water to use, the right to ask the Commission to pass upon the question of diligence in the prosecution of the work on his project under the terms of section 1416 of the Civil Code, and if approved, to issue a certificate of due diligence fixing a time for the complete application of the water, thus giving him the same measure of protection from litigation as those acquiring rights under the general provisions of the act. There have been eighteen applications received by the Commission under this section.

Section 42 limits the scope of the act to surface water and to subterranean water flowing through known and definite channels. Applications are occasionally received for waters to be developed from wells or other works drawing from a body of broadly diffused percolating water. In such instances, if the applicant desires, the application is allowed in order to establish a public record of the initiation of the use of the water.

Character of Supervision.

The purpose of the program of supervision of appropriations outlined in the act in sections 11, 12, 15, 16, 17, 18, 19, 20, 22, 23 and 38, is to facilitate an efficient use of unappropriated waters without injury to the owners of vested and prior water rights. The following are the more important features of the prescribed supervision as worked out in practice by the Commission.

1. Appropriators are required to file complete information on standardized forms within a reasonable period of time and in accordance with rules and regulations prescribed by the Commission.

2. Permits are issued subject to existing rights, and with definite priorities, for definite use and for amounts of water commensurate with needs of the appropriator and not in excess of the available supply of unappropriated water. A reasonable time is prescribed for

PLATE IV.

Pump house and discharge pipes of Sutter Basin Company pumping plant.

PLATE V.

Hillside orchard irrigation.

the construction of works and application of water to use. A permit may be refused where "such appropriation would be detrimental to the public welfare."

3. The construction of works described in the application and the placing of the water to beneficial use is under inspection by the Commission and permits may be revoked if work is not prosecuted with due diligence, and water put to use in accordance with the terms of the permit.

4. Licenses are issued after the construction work has been completed and water put to use in accordance with the terms of the permit.

5. Changes in point of diversion or place of use are allowed only upon petition and a showing that no injury will result to other appropriators or legal users of water.

6. Record is kept of the ownership of water rights and evidences of transfer are required to be placed on file with the Commission when such occurs.

7. Section 38 of the act defines diversion of water without a permit to be a trespass upon the state, and authorizes the Commission to prosecute such trespass through appropriate court action.

Administrative Routine.

The Water Commission Act as originally drawn provided that all business coming before the Commission should be handled by the Commission as a whole. In practically every other irrigation state, however, a single officer has authority to pass upon applications to appropriate water, subject to an appeal to the water board. The Water Commission recommended in its Second Biennial Report that a change be made in the act providing for a Commission to include one executive member at a stated salary, and two associate members on a per diem basis, the executive member to have authority to act upon applications to appropriate water with right of appeal to the full Commission. The Legislature at its 1919 session amended the act in accordance with this recommendation (section 1) and the new procedure has been in effect for over a year.

The office routine through which each application passes before approval or rejection by the executive member, commences when it is received by the Secretary. If definite as to the four items of source of supply, amount of water to be appropriated, use to which water is to be applied, and point of diversion, and if accompanied by the filing fee prescribed by law, it is given a number which indicates its relative priority. It then goes to the Engineering Department for a preliminary checking, and action is taken on any request for time within which to make surveys and maps. When the applicant has completed the application, which may require from one month to as many as eighteen

months, depending upon the magnitude of the project, another examination and check is made by the Engineering Department, and if any omissions or errors are found a formal notice is sent to the applicant, giving sixty days within which to perfect and amend. Under the law, an application cannot lose its priority before the expiration of sixty days from the date of such a notice, so that this is an important step in the procedure.

As soon as an application is completed and in proper form, notices are sent out by the Engineering Department to water users whose interests might be affected, and it is advertised in a local newspaper. In the case of small applications and those which are not protested, action to approve or reject can usually be taken at once. Where the application is protested or there is question as to the supply of unappropriated water, the Engineering Department is called upon to make an office report, and if necessary, a field investigation. The applicant may also be called upon to submit engineering data. The field studies may require a year or more if stream flow measurements are not available or if the question of the effect of the proposed diversion upon developed underground water supply is involved. In complicated cases, informal conferences are often called, at which the executive member or an engineer is present. As a result of such conferences a clearer understanding of the situation is gained by all concerned, and limiting permit clauses are often suggested that are satisfactory to applicant and protestant, upon the basis of which protests are withdrawn. Formal hearings with taking of testimony are very unusual, it ordinarily being possible to submit the required data in the form of engineering reports and attorney's briefs.

The application is finally acted upon by the Executive Member when all necessary data has been received, and if approved, a permit prepared by the Engineering Department. Definite dates are placed in each permit when construction work shall begin and be completed, and when the water must be completely applied to use. Inspections are made by the Engineering Department from time to time, and the Commission has the power to revoke a permit after formal hearing if the work is not completed according to the permit terms. Successful attempts to hold water rights "in cold storage" are thus a thing of the past under the Water Commission Act.

The constant endeavor throughout these proceedings is, so far as possible, to forestall future litigation by clearing up misunderstandings and effecting satisfactory compromise and agreements. This policy is of advantage to the applicant, for it enables him to ascertain, before making heavy expenditure, what conditions he has to face. In this connection, it should be noted that thus far in the history of the Commission practically no attack has been made in the courts against

the rights acquired under any permit issued. Another purpose in view is the protection of the investor, especially on projects where the water is to be used by parties other than the applicant. Permits are denied in such cases where there is insufficient water available to make the project feasible. In a number of instances the loss of capital through investment in ill-advised projects has been prevented.

The act as amended in 1919 provides for an appeal from the action of the executive member to the Commission as a whole. Since the amendment became effective 409 applications have been acted upon and 152 permits granted. There have been but three appeals, and in each instance the Commission has sustained the action of the executive member.

Throughout the routine procedure of acting upon applications the Engineering Department of the Commission is called upon heavily for work in checking applications, meeting applicants and the public, digesting protests, making field investigations and reports, and inspecting the progress of work and application of the water to use. The efficiency and speed with which applications can be acted upon depends largely upon the adequacy of the Engineering Department to meet the demands made upon it. This in turn depends upon the funds available to the Commission. At present these are inadequate to enable the Department to keep pace with the greatly increasing volume of business to be handled.

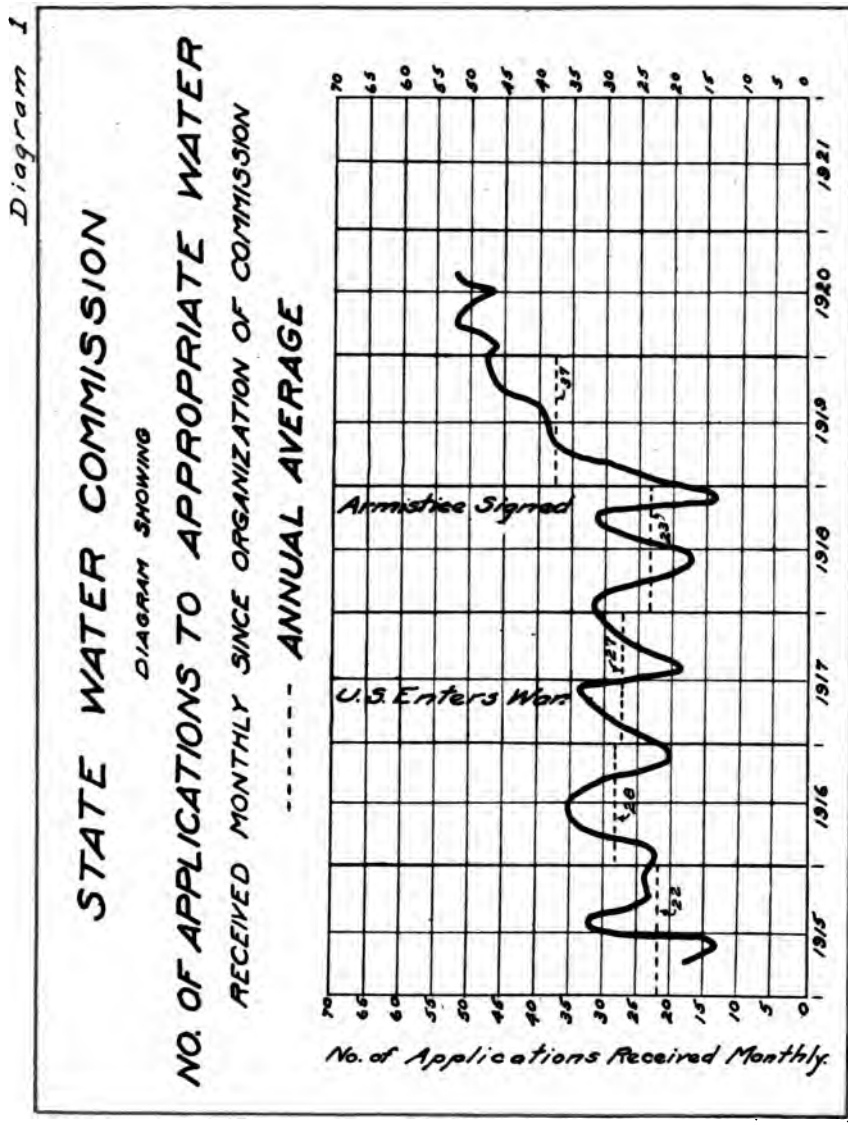
Statistical Summary of Applications.

The following tabulation gives a comparative summary by biennial periods of applications received, permits granted, and licenses issued, since the organization of the Commission.

TABLE 1.

Summary of Applications During Biennial Periods.

	Totals to Dec. 1, 1916	Dec. 1, 1916, to Sept. 1, 1918	Sept. 1, 1918, to Sept. 1, 1920	Totals
Applications received	531	538	928	1,997
Permits granted	192	261	263	716
Applications withdrawn	39	24	135	198
Applications rejected	50	86	217	353
Applications pending—end of period	250	417	730	
Permits granted—				
Agricultural	162	203	195	560
Power	7	14	23	44
Mining	23	35	33	91
Municipal	0	1	2	3
Domestic	0	8	10	18
Totals	192	261	263	716
Licenses issued—				
Agricultural	3	27	36	66
Power	1	2	9	12
Mining	0	5	9	14
Domestic	0	2	5	7
Totals	4	36	59	99



The outstanding feature of the table is the great increase in applications received during the biennial period just closed, the number being practically the same as the total of that during the two preceding biennial periods.

The increase is illustrated more strikingly and in detail by Diagram 1. Figures taken from this graph are as follows:

Average number applications received January to August, 1920---49 per month
Average number applications received January to August, 1919---34 per month
Average number applications received January to December, 1919-37 per month
Average number applications received 1915 to 1918----------25 per month

In other words, applications were received during the first eight months of 1920 at a rate 50 per cent greater than during the same period in 1919, and at a rate nearly twice the average of the previous four years. The graph is remarkable in its accurate portrayal of the general business conditions in the state during the period covered, and in particular the retarding effect of the war and the subsequent renewal of activity on a greater scale than before. The close similarity suggests the reason for variation in the rate of receiving applications.

Another fact of importance brought out by a detailed study of applications is the greater relative size of projects proposed during the last two years as compared with those of the preceding four years. This is indicated by the following tabulation:

TABLE 2.

Greater Size of Projects Under Applications During Past Two Years, as Indicated by Ratios of Acreage and Horsepower per Application.

Period	Agricultural applications (Ratios of acreage per application)	Power applications (Ratios of horsepower per application)
1915-18	1	1
1919	1.5	3.25
1920	1.75	7.50

The greater average size of projects means greater complexity and adds much to the amount of office work per application involved in checking and bringing to completion. It also increases the probability of protest and the necessity for field investigation before permit is issued. Considering the two factors of increased number and increased importance of applications, it is not an exaggeration to state that the volume of work before the Commission, and particularly the Engineering Department, has increased threefold during the past year as compared with the average of the four years, 1915 to 1918. The funds available to the Commission, on the other hand, are considerably less than in those years, both in amount and in purchasing power. The Commission, because of inability to increase the personnel of its staff, is thus becoming less and less able to handle applications with despatch, and this condition will become worse as time goes on, since the great bulk of new applications are still in an incomplete state awaiting the completion of surveys, etc., on the part of applicants. It is thus obvious that if the Commission is to function with satisfaction to the public it must have increased appropriations at the coming session of the Legislature.

Agricultural Applications.

Applications for permit to appropriate water for agricultural purposes are received by the Commission in greater numbers than for

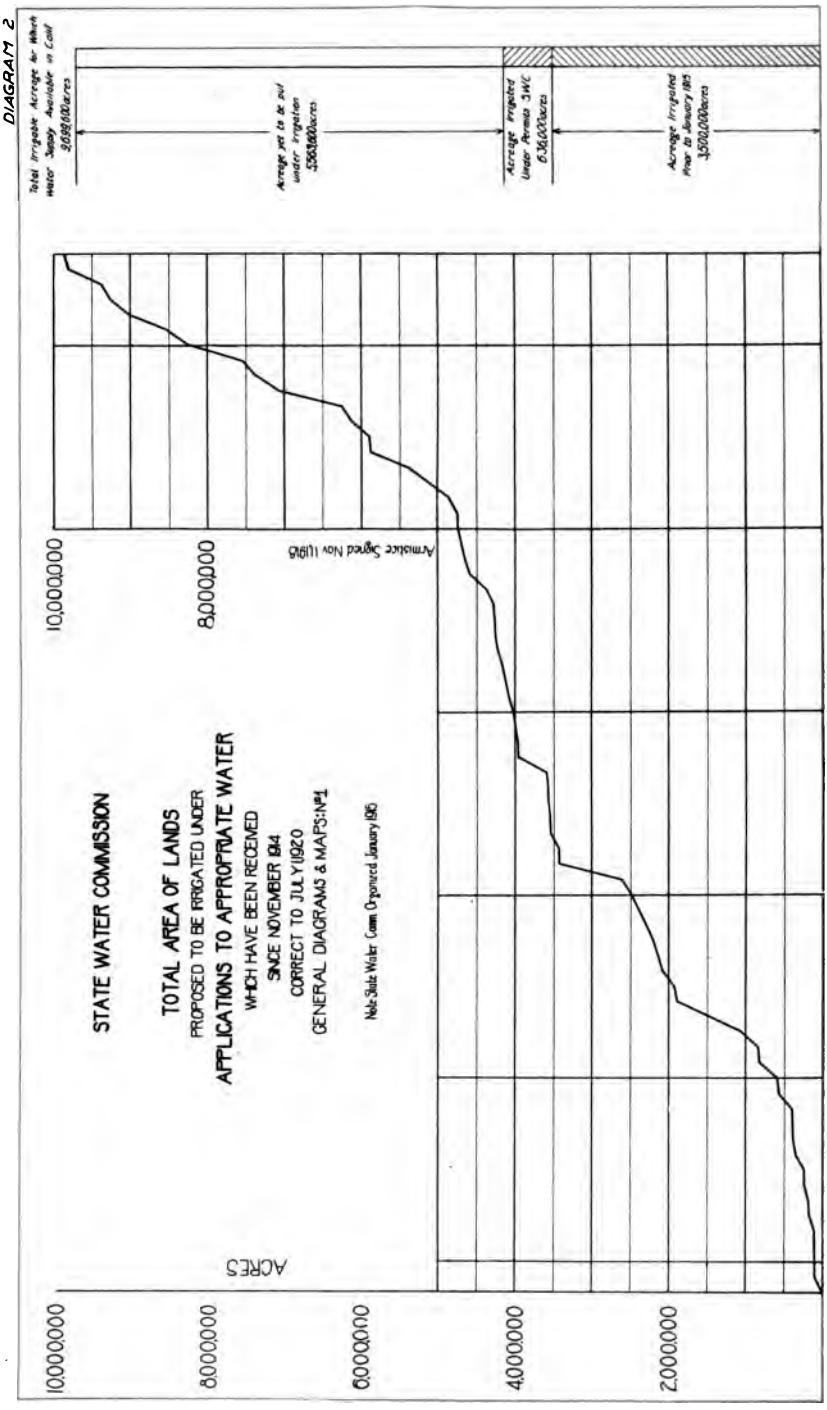


DIAGRAM 2
STATE WATER COMMISSION
TOTAL AREA OF LANDS
PROPOSED TO BE IRRIGATED UNDER
APPLICATIONS TO APPROPRIATE WATER
WHICH HAVE BEEN RECEIVED
SINCE NOVEMBER 1914
CORRECT TO JULY 1920
GENERAL DIAGRAMS & MAPS: No 1
Note: State Water Comm. Organized January 1913
ACRES
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
10,000,000
8,000,000
Armistice Signed Nov 1918
Total Irrigable Acreage for Which Water Supply Available or Could 8,000,000 acres
Acreage yet to be put under irrigation 3,963,360 acres
Acreage Irrigated Under Permits 1912 4,036,640 acres
Acreage Irrigated Prior to January 1913 3,500,000 acres
1915
1916
1917
1918
1919
1920

any other purpose, the proportion of the total being approximately 75 per cent. These applications are for a wide range of acreage and type of project. Many are for the irrigation of small individual tracts of land by direct diversion from a stream or spring. Others are for larger individual tracts and involve the construction of small storage reservoirs. Still others are for large projects, usually under irrigation district organization, including many tracts of land and covering areas of from several thousand up to two or three hundred thousand acres. Such projects usually contemplate a combination of direct diversion during the high water season and draft on storage during the summer months. Many applications for large acreages have been filed, both in the San Joaquin and Sacramento valleys. The latter are largely proposing to divert from the Sacramento River. The total flow applied for on this stream exceeds an amount more than two and one-half times the normal summer flow. This condition must be met by construction of storage reservoirs if further development is to continue.

The relative activity in proposed agricultural development during the past two years as compared with previous years is well shown by Diagram 2. This graph represents the total acreage on the first of each month for which agricultural applications have been received since November, 1914. During the years 1915 to 1918, the average area for which applications for water were received annually was approximately 115,000 acres. Beginning January, 1919, the area has suddenly increased to 340,000 acres annually, an amount three times as great as that of previous years. This activity has been stimulated by the high prices for farm products which have prevailed during recent years.

As indicated at the right of the diagram, the total irrigable acreage of the state for which water supply is available is approximately 9,699,600 acres.* Of this 3,500,000 acres, or 36 per cent of the total, was irrigated January, 1915, at the time the Water Commission was organized. Since this date, water rights have been initiated under the Water Commission Act, and permits issued for 636,000 acres, or 7 per cent of the total, much of which is now under irrigation. There remain 5,563,000 acres yet to be put under irrigation. Applications for irrigation received during the eighteen months ending July 1, 1920, cover an area of approximately 5,000,000 acres, and the total of all agricultural applications now pending before the Commission exceeds 6,000,000 acres. It is thus apparent that giant strides in initiation and preparation of plans for the complete irrigation of the irrigable land of the state are now in progress.

*Irrigation Resources of California and Their Utilization, by Frank Adams. (Bulletin 254, Office of Experiment Stations, U. S. Dept. of Agriculture, p. 87.)

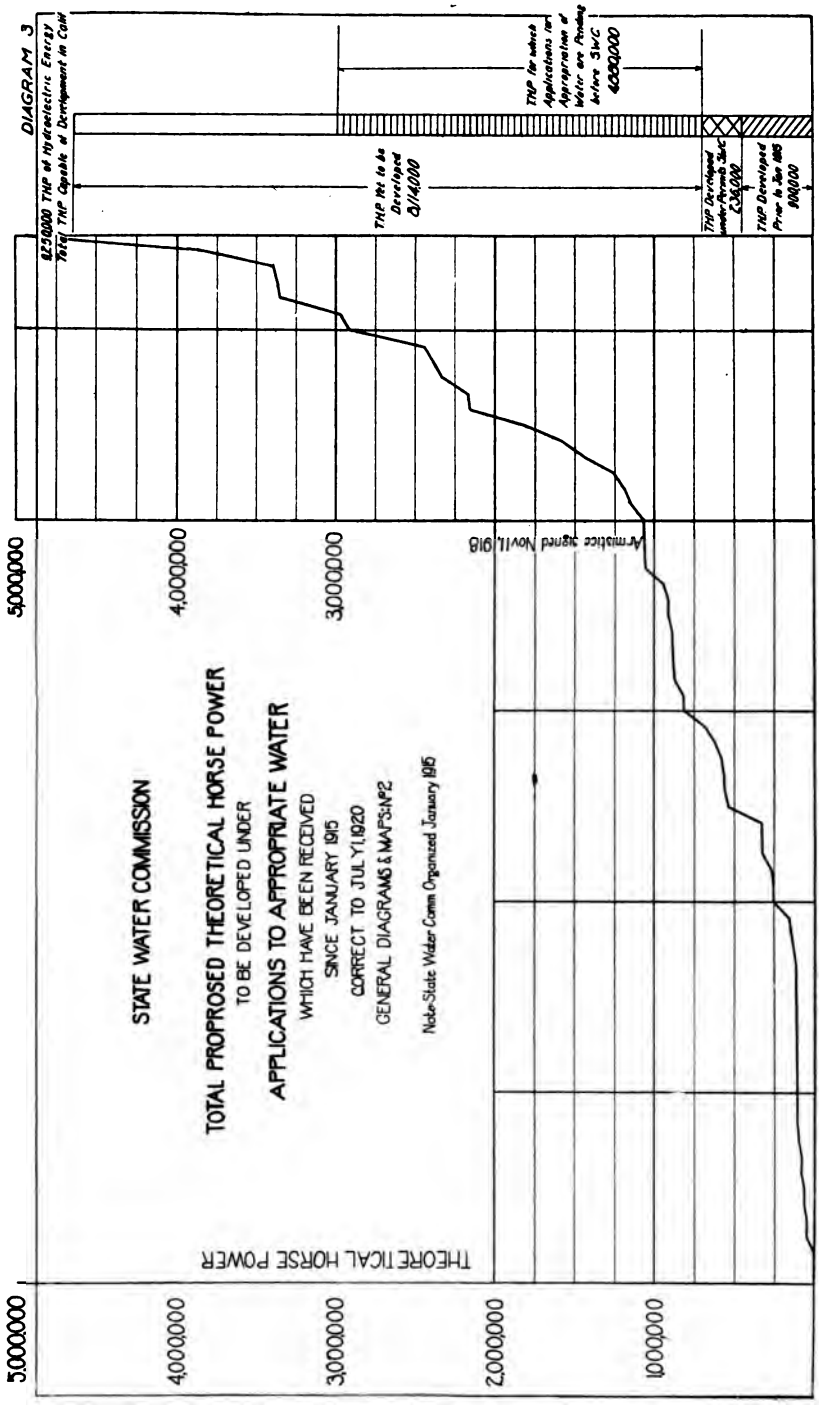


DIAGRAM 3
THP Developed under Permits 3a-c 236,000
THP Developed Prior to Jan 1915 900,000
THP for which Applications for Appropriation of Water are Pending before SWC 4,000,000
THP Yet to be Developed 9,140,000
THP Capable of Development in Cal
Total 14,239,000 THP of Hydroelectric Energy
Armistice Signed Nov 11, 1918
STATE WATER COMMISSION
TOTAL PROPROSED THEORETICAL HORSE POWER
TO BE DEVELOPED UNDER
APPLICATIONS TO APPROPRIATE WATER
WHICH HAVE BEEN RECEIVED
SINCE JANUARY 1915
CORRECT TO JULY 1, 1920
GENERAL DIAGRAMS & MAPS No 2
Note-State Water Comm Organized January 1915
THEORETICAL HORSE POWER
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
1915
1916
1917
1918
1919
1920

A list of the more important projects now definitely proposed, as indicated by the applications on file with the Commission will be found on Table 3 at the end of the report.

Power Applications.

Applications for permit to appropriate water for hydro-electric power development, although next in importance to agriculture, are much less in number, being approximately 5 per cent of the total. The applications are most of them for large developments, involving large capital investment, there not being the opportunity for individual effort that exists in agriculture. The important projects are located on streams tributary to the Sacramento and San Joaquin valleys, and on Owens and Klamath rivers. Most of the applications are for projects contemplated by corporate interests, although the city of Los Angeles has recently made extensive filings on San Joaquin valley streams. Storage is a feature of most projects. In a few instances companion agricultural applications have been filed for the use of the water for irrigation after leaving the lowest power house. This is not the rule, however, the larger companies preferring to remain exclusively in the power business.

The activity in prospective power development during the past eighteen months, as indicated by Diagram 3, is greater than in agriculture, and has been especially marked since the passage of the Federal Water Power Act in June, 1920. The graph represents the total theoretical horsepower on the first of each month for which applications have been received since January, 1915. During the period 1915 to 1918, the average rate was 280,000 theoretical horsepower per year. Since January, 1919, the rate has increased to 2,530,000, an amount nine times as great as that of previous years.

As indicated at the right of the diagram, the total hydro-electric power development of the state at the time the Water Commission was organized was 910,000 theoretical horsepower, or 10 per cent of the total ultimate development, which, according to various authorities, is 9,250,000 theoretical horsepower.* Since the Water Commission Act has been in effect, permits have been issued for water rights for the development of 236,000 theoretical horsepower, or about 2 per cent of the total. There are pending before the Commission applications totaling 4,880,000 theoretical horsepower, or 52 per cent of the total ultimate development. This indicates that a remarkable program of power development is now under way.

A tabulation including a description of the more important proposed hydro-electric projects as indicated by applications on file with the Commission will be found in Table 4 at the end of this report.

*Electrical World, March 20, 1920, p. 658.

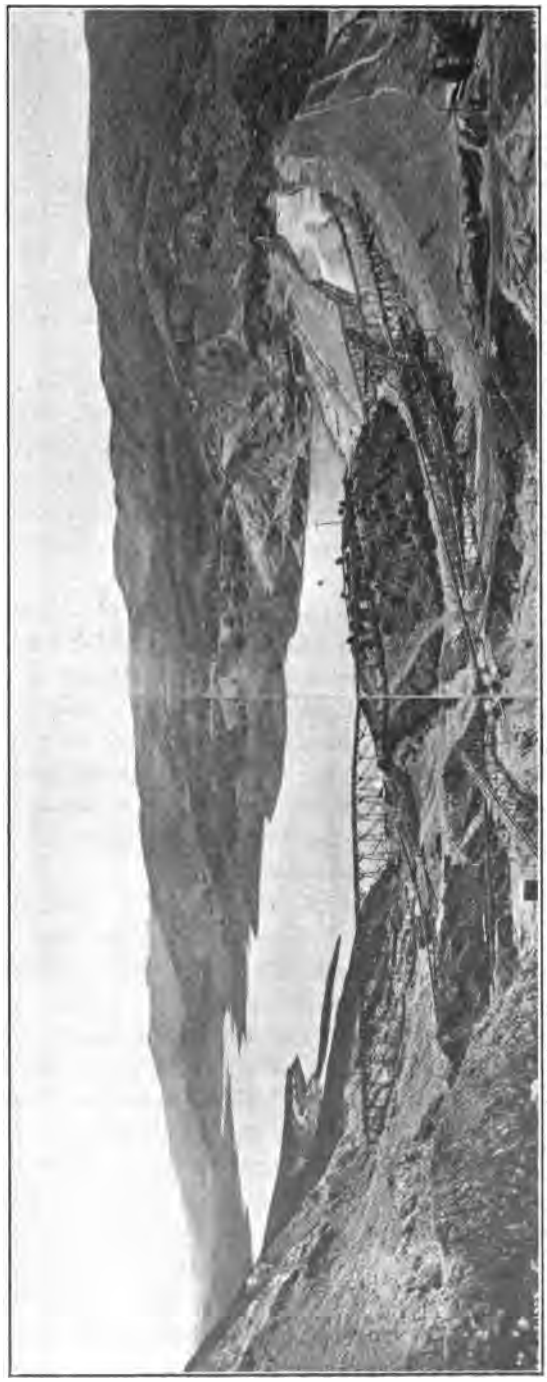


PLATE VI.

San Pablo Dam and Reservoir under construction by East Bay Water Company for Municipal supply of East Bay Cities.

Mining Applications.

The use of water in California for mining, although formerly of greater importance than for any other purpose, is now far surpassed by that for both agriculture and power. The number of applications received, however, exceeds that for power, the proportion of the total received being approximately 12 per cent, as compared with 5 per cent in the case of power. The reason for this apparent discrepancy is the greater opportunity for individual effort or for enterprise with small capital. Most of the proposed mining diversions are for hydraulic operations. Siskiyou County appears to offer the most attractive opportunities at the present time. Table 5 at the end of this report lists the more important developments proposed as indicated by the applications on file.

Municipal Applications.

Municipal applications are those made by municipalities for domestic and strictly municipal purposes, and do not include those made for power development or primarily for agricultural use. With respect to such applications, the Water Commission Act (section 19) contains the following provision:

> The application for a permit by municipalities for the use of water for said municipalities or the inhabitants thereof for domestic purposes shall be considered first in right irrespective of whether they are first in time; *provided, however,* that such application for a permit or the granting thereafter of permission to any municipality to appropriate waters, shall not authorize the appropriation of any water for other than municipal purposes.

More or less confusion exists in the minds of many people as to the extent of preferential rights acquired by cities initiating water rights under the Water Commission Act. From the above quotation it is clear that such rights are limited to domestic and strictly municipal uses, and that the act merely confirms time honored custom and the decisions of the courts in placing the right to the use of water for human consumption above that for its use for commercial purposes.

The important municipal applications received by the Water Commission during the last biennial period are listed in Table 6 at the end of this report.

Permits Issued.

There were but few permits issued for large projects during the last biennial period, largely because of the war and financial conditions. Among the more important permits may be mentioned that issued to the Happy Valley Irrigation District for irrigation of 18,110 acres at an estimated cost of $453,690; to the Natomas Company of California for irrigation of 14,510 acres at a cost of $350,000; to the Sutter-Butte Canal Company for irrigation of 27,500 acres; to T. B. Cross for the irrigation of 8436 acres, from the Sacramento River; to the San Joaquin

Light and Power Corporation for development of 63,636 theoretical horsepower at a cost of $4,000,000; and that issued to the Sierra and San Francisco Power Company for development of 31,704 theoretical horsepower, at a cost of $740,000. There were no important permits issued for large storage reservoirs, although in connection with irrigation and power projects approximately fifteen small reservoirs were to be constructed. A tabulation listing the essential features of the important permits issued will be found at the end of this report as Table 7.

Relation Between Power and Irrigation.

The greatly increased activity in hydro-electric power development on all the important streams of the state, as indicated by Table 8, brings to the forefront problems of greatest public interest. The solution of these problems will affect not only the communities depending upon a common source of water supply, but also the whole state and portions of adjacent states. These problems arise from conflict in interest which often develops between power and irrigation interests using water from the same stream. These conflicts are often waged between interests of unequal strength and are of such far reaching effect that the state can not afford to stand aloof and let them proceed as though they were the contests of private interests in which no one had any concern but the contestants. In fact, a correct solution of these problems is necessary to the well ordered, normal and balanced growth of the state.

In the case of power projects for which water rights are initiated under the Water Commission Act, there exists a means of adjustment of conflicting interests by an administrative arm of the state, namely the Water Commission. The law and the regulations of the Commission require that publicity be given new projects in order to bring them to the attention of the interests concerned. A statement of proposed plans is also required, and is made of public record at the office of the Commission. On the basis of this information, water users can form an intelligent opinion as to the extent of possible injury, if any, which may result to them. By means of protests filed, the Commission is informed of possible conflict and through its Engineering Department can obtain the facts. The informal procedure of the Commission permits of full discussion and understanding of the situation on the part of all concerned. The Commission has opportunity to suggest a common ground of agreement where differences occur and thus reduce to a minimum the probability of future conflict and litigation.

There are three general types of streams to be considered with reference to possible conflict of power and irrigation interests:

1. Natural power sites located entirely above points of direct diversion or storage for agricultural use, as for example, on Kings and San Joaquin Rivers.

2. Natural power sites located partially above and partially within the vertical range of elevation of direct diversion or storage for agricultural use, as for example, on American and Yuba Rivers.

3. Natural power sites entirely below points of direct diversion for agricultural use, as for example, on Klamath and Pit Rivers.

Power projects considered with respect to the handling of water may be either strictly natural flow plants, natural flow plants with canal and forebay pondage, or combined natural flow and storage plants, in which the storage may be either seasonal or with a carry-over from year to year. There is usually no material reduction in the total amount of water flowing in the stream as the result of power development, except in instances when water is diverted from one drainage area into another. The principal change is in the character of the flow of the stream and its diversion from certain sections of the natural stream channel.

Irrigation projects may either depend entirely upon direct diversion from natural stream flow for immediate delivery to the land, or for storage in reservoir sites away from the stream channel; or depend partially upon direct diversion from natural flow augmented at times of shortage by storage water released from a reservoir in the natural channel at some distance above the point of diversion. There is an immediate reduction in flow of the stream to the extent of diversion for irrigation. After a few years, however, if the irrigated lands are tributary to the stream, there begins to be a well sustained return seepage flow which may be as great as 30 per cent of the water diverted.

The two most important sources of conflict between power and irrigation interests are, therefore, as follows:

1. Abnormal and superimposed fluctuations of stream flow at points of direct diversion for irrigation, resulting from power plant operating conditions. These fluctuations may be seasonal, daily or hourly. They may result from local load conditions only, in the case of an isolated power distribution system, or, may result from a variety of circumstances in the case of a plant feeding into a large transmission system or several interconnected systems.

Such a condition can be remedied, depending upon the character of fluctuation and the physical situation, either by storage below the lowest power house and above irrigation diversion, by pondage immediately below power house tail-race, or by synchronous by-pass regulation at the water wheel. The degree to which the remedy can be made effective depends upon the amount of money expended. In general,

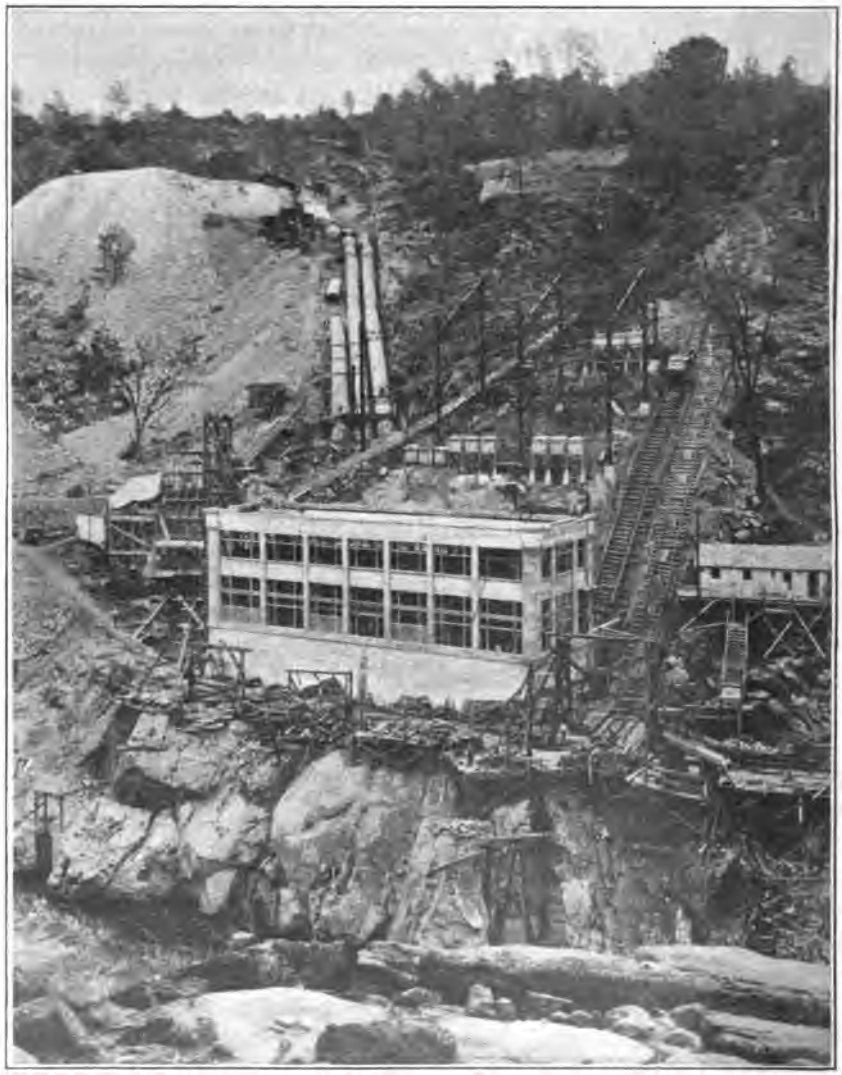


PLATE VII.

Kerckhoff power house on San Joaquin, where water is returned to the stream after generation of 50,000 horsepower of electric power.

satisfactory adjustment can be accomplished without imposing an unreasonable financial burden, particularly when the direct and indirect cost of avoided litigation is considered.

2. Reduction of stream flow resulting either from irrigation diversion above power diversion, from power diversion by-passing irrigation diversion, or from diversion for use outside the drainage area. This type of conflict is more difficult of adjustment than the first, and decisions must be made in each individual case on its own merits considering the greatest good to the greatest number.

The above analysis of the problem indicates some of the complexities that may arise. The Water Commission realizes that these problems can be correctly solved only with a clear understanding of the technical engineering features involved. To the extent that its funds permit, the Commission has made provision for this by the assignment of a competent hydraulic engineer to the special study of power applications and the conflicts which may arise thereform. The effectiveness of the Commission in adjusting conflicts will be curtailed in this respect, however, until adequate funds for engineering investigations are available.

Summary.

The work of the Water Commission prior to September 1, 1920, in the supervision of appropriation of water may be briefly summarized as follows:

1. Applications to appropriate water have been received for the irrigation of 10,890,000 acres, and for the development of 5,590,000 theoretical horsepower of electrical energy as well as for various mining and municipal uses. Sixty per cent of the acreage and 83 per cent of the electrical horsepower has been applied for during the biennial period ending September 1, 1920.

2. Permits to appropriate water have been issued for the irrigation of 618,400 acres, and for the development of 243,000 theoretical horsepower of electrical energy.

3. All permits issued have accurately defined the water right as to amount, priority, point of diversion, use, etc., and the construction of works and application of water to use in accordance with permits has been done under the supervision of the Commission.

4. A complete record of all applications for appropriations, permits and licenses, since December 19, 1914, is kept on file and is open to inspection at the office of the Commission in San Francisco, and copies of all permits issued have been filed with the county recorders.

5. Under this system of supervision of water titles, the over-appropriation of streams has been prevented, the possibility of litigation resulting from initiation of new diversion has been reduced to a minimum, the investor in irrigation or power development works has been given a much greater degree of security, and loss through investment in ill advised projects has been prevented.

CHAPTER III.

ADJUDICATIONS AND REFERENCES.

One of the principal functions of the State Water Commission under the terms of the Water Commission Act, is to supplement with a more effective and expeditious method the work of the courts and other state agencies in determining the priorities, extent, uses and relationships of rights under appropriation or riparian ownership acquired under the law as it existed prior to the passage of the act. Such work must be undertaken as rapidly as possible, in order to clear the way for the fullest economic use of our admittedly inadequate water supply, either in discovering what portions of normal flows still remain open to appropriation or riparian use, and to admit of the fullest possible storage of flood runoffs. The act provides a complete machinery for the adjudication of rights under appropriation covering an entire stream system. Riparian ownership may be determined under reference by a court in pending suits when desired, and in other disputes the Commissioners frequently act as arbitrators at the request of the disputants. The machinery provided in the act for the wholesale determination of rights under appropriation covering a stream system in one action has been taken from the laws of other states where this method has been found the most effective, rapid and economical one to handle such cases. The California procedure follows most closely that of Oregon and Nevada, where such laws had been in active operation for some years prior to the California enactment. This procedure has been so thoroughly tested in the courts of these states as well as in the Federal and United States Supreme Court that its constitutionality is now unquestioned. It was necessary, however, to amend the original act in some respects to make it apply to the recognition of the dual system of riparian and appropriated rights in this state.

Determination of Water Rights by the Courts and by the State Water Commission.

Prior to the passage of the Water Commission Act, the only tribunals with authority to define water rights were the courts. Court litigation is unsatisfactory in many respects, however. The primary function of the courts is not to make determinations of water rights, but to decide questions in dispute and to administer equity between litigants before the court. In a water right suit, the object of the court is to protect property rights in water through the medium of the injunction. It was only because it often was necessary to make a determination of rights before granting injunctive relief that the courts have made a practice of determining the relative rights of litigants in an action. It

is seldom attempted to determine the rights of the litigant as against all other owners of water rights on a stream. The courts are not instituted for the purpose of determining water rights, and court procedure is not adapted to do it. The procedure is cumbersome, slow, costly and usually devoid of definite or satisfactory results.

The following are specific reasons why court procedure is inadequate as a method of defining existing water rights.

1. Courts do not act upon their own initiative or the desire of water users, but must await a conflict between water users and the filing of a complaint by the injured party.

2. The parties before the court seldom include all owners of water rights on the stream where controversy arises, and the determination of rights is limited to that which is necessary for a solution of the question involved in the litigation.

3. Decrees when rendered are inadequate for protection against water users not made a party to the suit.

4. There is no method by which a decree can be effectively and quickly enforced when necessity arises. Contempt proceedings for violation of the decree are ineffective and costly and subject to the usual delay and hindrance of court routine.

5. Judges do not have the time, in the midst of their other duties of solving the multitude of complex legal problems that come before them, to make the necessary study of actual conditions on the ground or of the various engineering and physical problems which arise in passing upon practical questions as to the use of water. These questions are often far more important than the legal principles which are involved.

6. Judges have no means of ascertaining facts completely and accurately, but must depend entirely upon the testimony of biased witnesses. As a result, although correct as to the law, decrees are often indefinite, uncertain, and in some cases even in error as to fact, especially as to the quantity of water awarded.

7. Court procedure is cumbersome and slow, being governed by intricate rules of pleading, and subject to delays for long arguments, interposing of objections, the taking of voluminous testimony as to fact, and the opinions of partisan expert witnesses. When all testimony is before the court, further delays are occasioned by arguments by attorneys and preparation of briefs, and finally by the study of unfamiliar technical problems by the court. As a climax, when the decision has been rendered, the case is generally appealed, and when in the course of years, the final decision is obtained, conditions may have so changed that the result of the whole proceeding is worthless.

8. Court litigation is costly and to the man of limited resources means bankruptcy. It is only the large organized interests or large land owners who can afford to undertake litigation. The average water user prefers to suffer the encroachment of others, or to protect his rights by "rock rolling" or by resort to physical violence.

9. Litigation is the result of conflicting claims and breeds strife and animosity. The latter is encouraged by the delay and hindrance of court procedure.

10. Courts are largely interested in the preservation and protection of private interests and can not of their own initiative consider the general good of the public.

Contrasting with the above are the following facts with regard to the method of determining water rights provided by the Water Commission Act. These are arranged in order, with numbers corresponding with those above:

1. The Water Commission can act either upon petition of one or more water users or upon its own initiative, if upon investigation it finds the facts and conditions are such as to justify such a course.

2. All claimants to water or the use of water on the stream are required to appear before the Commission and make proof of their claim.

3. Findings and the decree are definite as to priority, amount, etc., and the water right certificate, when issued, affords the owner tangible and reliable evidence upon which to base his right or title.

4. With a system of supervision of diversions from natural streams by public officials in effect, a decree can, when necessity arises, be quickly and effectively enforced by an administrative officer familiar with the local conditions.

5. Members of the Water Commission devote their time solely to the problems involved in the use of water, have time to become personally familiar with the ground and to study the practical questions involved, as well as the law. The act also provides that they be chosen because of their practical knowledge or experience in the use of water.

6. The Commissioners have at their command unbiased and specially trained engineers to gather the facts and advise regarding complex physical conditions.

7. The procedure before the Commission is informal and the time required very short as compared with court procedure. All engineering facts are presented in the form of maps, tables, and reports, and most of the historical facts through the medium of written claims filed by water users. Most of the possible contests between claimants are forestalled by the opportunity which claimants have during the progress of surveys and before the final hearings to gain information and advice from the Commissioners or engineers as to the preparation of claims.

As an example, on the Stanislaus River Adjudication, there were but two contests which came before the Commission at the formal hearing, out of 3920 which were possible.

8. The cost of the adjudication procedure to the water user is nominal, being comparable with that of obtaining an abstract of title to land.

9. The adjudication procedure is a careful and impartial investigation of the facts where water right owners, having no particular disputes among themselves, submit their claims with the desire of the average man to be reasonable and fair and recognize the rights of others.

10. The Commission must consider the rights of the public in the surplus and unappropriated waters of the streams of the State, as well as the rights of private individuals.

The advantages are all in favor of the adjudication procedure before the Water Commission. The latter does not, however, overlap or conflict with the authority and jurisdiction of the courts. It is not a "water court" and does not attempt to settle disputes between litigants. This is distinctly the sphere of the courts. What it does do, however, is to prevent needless litigation by determining established rights in advance of litigation, and thus lighten the burden of work before the courts. It is an institution which the courts should welcome, and this is gradually beginning to be realized, as the provisions of the act are applied and its purpose becomes better understood.

Adjudications.

STANISLAUS RIVER.

The first and largest adjudication undertaken, and now about completed, covers the Stanislaus River drainage. This adjudication was undertaken on the petition of the Oakdale and South San Joaquin Irrigation districts, representing a total of 145,327 acres on the main floor of the San Joaquin Valley. The stream traverses the counties of Alpine, Calaveras, Tuolumne, San Joaquin and Stanislaus, and includes some of the oldest rights in the State, dating back to the early fifties. With the waters from this stream carried through early mining ditch systems, the famous placer workings in Columbia, Angels Camp and Sonora were operated and some of the earliest power development was begun on these ditches. The demands for water for the great valley acreages and power for pumping and commercial purposes now call for the fullest utilization of the resources of this river. Plans for storage of the flood flows, all more or less dependent upon the settlement of the old rights, are being developed from the high Sierras for power to the lowest point on the watershed suitable for irrigation purposes. All the evidence in this case has been assembled and it is expected that the findings of the Commission will shortly be turned over to the courts

of the counties in which the rights have been established for approval or modification.

The abstract in the adjudication shows 81 rights claimed, covering 3321.96 second-feet for agriculture, 1494.67 second-feet for power, 119,289 acre-feet for storage, and 438 second-feet for public service.

This proceeding has demonstrated the efficiency and economy of this procedure as compared with the ordinary court process, and has the advantage of an impartial investigation and finding by the state itself, followed by a review by the courts allowing for correction of error or oversight by the Commission.

Other important adjudications are now under way, and there will be a large increase in the demand for this work when its great value as shown by the Stanislaus case becomes more generally understood.

WEST CARSON RIVER.

An adjudication of the rights on this stream, lying within the boundaries of California, was requested at an early date, but through a misunderstanding on the part of the claimants their petition was not filed until 1920.

These people living close to the Nevada line are familiar with the Nevada law under which the rights on this stream after it flows into that state had been adjudicated some years ago, and were desirous of availing themselves of the advantages of the California act as soon as it was adopted. In this case, it was necessary to make a complete survey of the area. This was completed by the Commission's engineer in charge early in the fall of this year. Proofs of claim have been filed, and the preparation of the abstract of these claims is under way. Hearings on contests will be held on the ground as soon as the necessary steps have been completed.

References.

A number of important references have been undertaken by the Commissioners at the request of contestants.

NILES CONE.

The most important of these is the litigation between the Alameda County Water District, representing the rich farm and garden lands along the course of Alameda Creek to the westward of the town of Niles, and the Spring Valley Water Company, supplying water to the city of San Francisco.

The company has for many years transported water through the East Bay mains across the southern end of San Francisco Bay at Dumbarton Point from this creek and the Livermore Valley. The company had acquired extensive rights from stream flows and wells and was undertaking important storage enterprises in reservoir sites at the heads of tributaries of the main creek. Irrigation from wells on the detrital cone of the stream supplying irrigation water for these lands became more and more extensive, developing a conflict of long standing

between the farmers and the company. On September 6, 1916, an agreement was entered into between the parties whereby the then Commissioners were to carry on an exhaustive investigation of the runoff and infiltration into the gravels of the cone and determine under what conditions the proposed storage should be made. The company agreed to furnish up to $10,000 per year for three years to make such investigation, and the Commissioners appointed Mr. Paul Bailey as engineer in charge of this work. The investigation was as thorough as it was possible to make it and stands as one of the most complete of its kind. Great pains were taken to employ the best methods known to engineering science and unusual care was taken in the exactness of measurements and observations. The Commissioners made their final determination late in December, 1920, (Appendices E and F).

NORTH FORK OF COTTONWOOD CREEK IN SHASTA COUNTY.

In the spring of 1919 a suit was brought in the superior court of Shasta County by the Bee Creek Ditch and Water Company, naming all of the other water users from the North Fork of Cottonwood Creek and its tributaries as defendants, and appealing to the court to establish the relative rights to the waters of that stream system. Upon motion of the counsel for the plaintiff, the court entered an order transferring the case to the Commission for investigation.

In its investigation the Commission followed the procedure outlined in the statute for adjudications initiated under the Water Commission Act. The maximum capacities of all of the ditches were measured and a series of measurements of the flow in the stream and of the diversions into the ditches were made, covering the entire 1919 irrigating season. The parties to the suit were able to agree as to the irrigated acreage under each ditch and consequently it was not necessary to make a survey of the irrigated land.

Proofs of appropriation were obtained from each party and an abstract of claims was prepared.

Practically all of the claims were contested, and April 12, 1920, was set as the date for hearing. At this time, before proceeding with a formal hearing, the Commissioner called an informal conference of attorneys and presented to them the data collected, together with a proposed schedule for the allotment of water. After three days of discussion, all of the parties to the suit signed an agreement stipulating that a report be made to the court, finding that each party was entitled to a definite quantity of water as determined by the Commission, with the provision that whenever the supply is less than the total amount allotted, the parties shall divide the water in the ratio that their allotments bear to each other.

SAN PEDRO CREEK.

San Pedro Creek in San Mateo County flows through a very fertile valley producing artichokes and garden truck for the San Francisco markets. The summer flow of the stream is inadequate to meet the demands for irrigation water. In order to obtain their fair share of the flow, a lower riparian holder brought an action in the superior court of San Mateo County asking for a determination of rights on the watershed. The court consigned the case to the State Water Commission as referee, in accordance with the provisions of section 24 of the Water Commission Act. The Commission has completed a field investigation covering a period of two years, in which a thorough study of the water resources of the watershed was made, and the areas subject to economical irrigation, with their respective water requirements, were determined. As all the claimants were riparian to the creek, what constituted a reasonable use of water on each tract was a most important feature of this investigation. Based on this work, the seven parties to the action in conference with the Commission, arrived at a division of the summer flow between themselves to which they all agreed to stipulate before the court. A schedule of distribution is now being constructed in accordance with the stipulated division of the flow. This will then complete the adjudication of rights on a watershed on which practically all claims were based on riparian rights.

HAT CREEK.

In the fall of 1919, a similar action to the one involving the water rights on the North Fork of Cottonwood Creek was brought by David Doyel et al. against all of the other water users on Hat Creek. This case was referred to the Commission for investigation by an order of the superior court of Shasta County dated March 29, 1920.

There are forty-two ditches diverting water from Hat Creek above its confluence with Rising River, supplying water for irrigation to forty-four users. The plaintiffs are lower users and claim both riparian and early appropriation rights.

During the past summer, the maximum capacities of all of the ditches have been measured, a survey of all of the ditches and irrigated lands has been made, and a series of stream flow measurements has been made on Hat Creek during the period of low flow.

As soon as the office work in connection with the data obtained has been completed, it is the intention of the Commission to call a conference of attorneys to discuss the feasibility of entering into a stipulation similar to the one signed by the water users on the North Fork of Cottonwood Creek.

RED ROCK CREEK.

This was one of the early references on which considerable work was done by the Commissioners, but failed of completion because of involved ownerships of land and other pending litigation. The stream flows from the southern slopes of the Warner range in northeastern California onto the Madeline plains near Ravendale in a region where water is very scarce and poorly applied because of remoteness from markets. The stream is small and irrigation under it is quite limited.

WILLOW CREEK.

This reference was a case entitled *Johnson et al.* vs. *Hill,* in the superior court of Lassen County, initiated at the suggestion of the Commission so as to include all water users depending upon riparian rights as well as rights by appropriation. It involved the use of water from Willow Creek regarding which trouble had arisen. The Engineering Department of the Commission made a careful hydrographic survey during one season and a report was filed with the court, embodying the results. The Commission's engineer also attended the trial as a witness. The findings were filed by the court and judgment entered in April, 1918.

CHAPTER IV.

DISTRIBUTION OF WATER FROM NATURAL STREAMS.

Water Master Service.

There has been a marked interest shown during the past two years on the part of California water users toward a proposal for the distribution of water from natural streams and lakes by public officials in accordance with defined rights, such as is practiced in other western states. The dry years through which the state has just been passing, together with demonstrations on two of the largest streams of the state of the practical accomplishments of the system, have done much to awaken water users to the need and usefulness of the public administration of stream diversions.

This principle has been adopted, and section 37 of the Water Commission Act gives the Commissioners power to supervise the distribution of water in accordance with the priorities established under the act, when such supervision does not contravene the authority vested in the judiciary of the state. While the power granted is broad in terms, the section does not specifically authorize the Commission to supervise the distribution of water under rights acquired before the act went into effect, or provide the necessary legal machinery under which to put it into practice.

It was probably felt at the time that it was necessary only to establish the principle, and that at a later date a future legislature might, on the recommendation of the Commission itself, under what experience it should have acquired, enact such additional laws as might be needed.

It has begun to be appreciated that the purpose of such a system is to provide an administrative method for distributing water from streams in times of shortage in accordance with priority of right, which will make it unnecessary at such times for the owners of water rights to go into court or to make "Winchester" expeditions upstream in order to get the water to which they may be entitled. It has also begun to be appreciated that without such a system, the construction of large reservoirs on natural streams is merely the stepping stone to endless litigation. With this changed viewpoint, it is believed that the time has arrived when there will be general support of a needed amendment to the Water Commission Act providing the detailed machinery for water master service.

The purpose of public administration of streams is to provide a means for impartial and accurate division of the waters in accordance with established rights. A complete determination of rights alone does

not accomplish this. Flowing water is difficult of measurement and few water users have the necessary knowledge or experience. Furthermore, the energy and vigilance of water users vary and some are more inclined than others to take advantage of natural position on a stream. Then again, upper users have no means of obtaining knowledge of conditions lower down on a long stream and may unwittingly take advantage of their position to the injury of prior diverters below. The constant variation in the flows of the streams makes necessary an equally constant adjustment of diversions, if inequalities and injustices are to be avoided. On most of our California streams there is always a variation between the day and night flow, and diminishing flow with the advance of summer. Late and early rains, as well as seasonal variations add other and unexpected problems to an equitable division of the flow. It is thus obvious that a system for division of the waters of natural streams among those entitled to its use is just as important and necessary as for a well-ordered irrigation system. Because of the importance to the community and the interest of the public in unappropriated waters, the State is the natural agency to undertake this duty.

Recent Experience in California.

Although there have been several streams in California where for many years the water users have, by mutual agreement, employed a zanjero, or water superintendent, to distribute water to the various ditches, the first instanees of State supervision have occurred during the past two years.

The ditch interests on Kings River, organized as the Kings River Conservation Association, were the first to appreciate the value of disinterested supervision of diversions, and in July, 1919, appealed to the Water Commission to appoint a water master to control headgate diversions of the waters of that stream. The reasons leading to this request can be ascribed primarily to the recognized need of settling all existing water rights on the stream prior to construction of the proposed Pine Flat storage project. Such a settlement had not been accomplished through fifty years of expensive court litigation, during the course of which 137 suits have been initiated. The futility of attempting to accomplish results through litigation had become apparant to all, however, and a schedule setting forth the priority and amount to which each ditch was entitled at various stages of the river up to 2000 second-feet had been drawn up and agreed to by all concerned.

This agreement specified that the water was to be divided by a repsentative of the State Water Commission. Under the terms of the agreement, the Commission appointed one of its engineers as water master, and the latter has successfully administered the stream for the

past season within the limit of flow specified. The water users have expressed great satisfaction with the results, and especially appreciate the freedom from uncertainty which they now enjoy, knowing that the interests of all are being served impartially, and that if their supply is insufficient, it is because there is insufficient water in the stream. Every effort is now being made to reach an agreement as to relative rights throughout the full range of flow of the stream to which rights have been acquired up to approximately 9000 second-feet, and it is to be hoped that this will be successfully accomplished. There are 45 ditches on the river which divert water, and the irrigated area served exceeds 625,000 acres. The total length of stream channel to be patrolled exceeds 90 miles. A detailed report appears elsewhere as an Appendix.

The Sacramento River during the current season affords another instance of state supervision of diversions. The threatened shortage of water supply from this stream was viewed with concern by water users early in the season. Through the medium of the Emergency Water Conservation Conference, an agreement was drawn up among owners of water rights including about 70 per cent of the land covered by irrigation projects above Sacramento City. The signers of the agreement placed in the hands of the conference not only the supervision of distribution from the stream, but the preparation of a diversion schedule. The conference adopted a schedule and appointed a Water Commission engineer as water master.

The latter had several assistants, and by a system of thorough inspection, reduced wasteful use to a minimum. There were 25 diversions irrigating 107,000 acres signed up under the conference agreement. A situation which threatened great loss of crops and much litigation among the owners of water rights along the stream was thus carried through without any litigation among local interests, and with but minor crop losses, although the flow of the Sacramento River was the least of record during the past twenty-three years. A more detailed statement of the work of the Emergency Water Conservation Conference appears in Appendix M.

These successful examples of distribution of water at times of shortage by public officials on the two most important irrigation streams of the state, undertaken at the request of local interests, go far to reassure the average water right owner and to indicate the benefits to be derived from legislation officially authorizing such a system. They also suggest the possibilities of state regulation of the release, transmission and diversion of storage water. Without the latter, no owner of a storage appropriation could be assured of receiving the water released into a natural stream from his reservoir, nor could water users below his point of diversion be assured that he was not wrongfully diverting water to which they were entitled. Without public supervision and policing of

streams, the operation of stream bed reservoirs on natural streams would be impracticable.

Experience of Other States.

The first state to adopt an effective water code was Colorado, in 1879. One of the best features of this act was its provisions for public distribution of water. These have been in effect, with minor changes, ever since adoption, and have served as a model for legislative enactments in other states. There are now but three of the seventeen so-called irrigation states that have not adopted a system of public distribution.

TABLE 9.

Water Codes in Irrigation States.

State	Date adopted or amended	Code provides for: Supervision of appropriation of water at central office	System for adjudication of water rights	Distribution of water from natural stream by public authority	Doctrine of riparian rights recognized
Arizona	1919	Yes	Yes*	Yes	No
California	1913, 1917	Yes	Yes*	Authority but no machinery	Yes
Colorado	1879, 1881, 1903	Yes—incomplete	Yes‡	Yes	No
Idaho	1903	Yes	Yes‡	Yes	No
Kansas	1917	Yes	No	No	Yes
Montana		No	No	No	Yes
Nevada	1903, 1905, 1915	Yes	Yes*	Yes	No
New Mexico	1907	Yes	Yes‡	Yes	No
Nebraska	1895	Yes	Yes†	Yes	Yes
North Dakota	1905	Yes	Yes‡	Yes	Yes
Oklahoma	1905	Yes	Yes‡	Yes	Yes
Oregon	1909	Yes	Yes*	Yes	Yes
South Dakota	1905	Yes	Yes‡	Yes	Yes
Texas	1913, 1917	Yes	Yes†	Yes	Yes
Utah	1903	Yes	Yes‡	Yes	No
Wyoming	1890	Yes	Yes†	Yes	No
Washington	1917	Yes	Yes‡	Yes	Yes

‡Colorado system—Right of water vested through beneficial use prior to enactment of code, determined by courts after physical data assembled by State Engineer, except in Colorado, where State Engineer has no connection with defining of rights.

†Wyoming system—Vested rights defined by an engineering board, subject to review of courts on appeal.

*Oregon system—Vested rights determined by an engineering board, subject to review and consequent confirmation or modification by court.

Of these states, Kansas is to a large extent in the humid belt and the need does not exist, and Montana is seriously considering the adoption of a complete water code with such a provision included. California,

the leader of progress, should see to it that she is not the last state to take this step.

The conditions which led to the adoption of the code in Colorado were much the same as now exist in California, namely, complete appropriation and use of normal stream flow and the necessity of increased reservoir construction to permit of further extension of irrigation. The system has worked well in Colorado, Wyoming and other states which have adopted it, and water users in these states would seriously object to a return to the old condition where every ditch looked after its own interests, and the one most actively and vigilantly superintended got the water.

Under the Colorado law, the state is divided into five divisions corresponding with the main stream system and these are again divided into districts to include one or more streams and their tributaries, covering an area which can be administered by one man. The latter is termed a water commissioner and his principal duty is to divide the waters of a stream among the ditches according to the prior rights of each as defined by adjudication and court decree. If necessary, he has authority to wholly or partially shut the headgates of later appropriators to satisfy earlier rights. He may also shut off the supply from any ditch under which water is, in his judgment, being used wastefully. The water commissioner is given power to enforce his actions in adjusting headgates. Each division is in charge of a division engineer who has general control of the water commissioners in his division, and to whom appeal may be made. The division engineers are under the general supervision of the State Engineer and ditch owners may appeal to the latter from decisions of the division engineers and thence to the courts. Water commissioners are paid by the counties and division engineers by the state. Water commissioners begin work only upon written demand of two or more ditch owners, or the order of the division engineer.

The provisions of the law in other states correspond generally with those in Colorado. In some other states, however, the division superintendents, with the State Engineer, form an administrative body. This body has direct charge of the water commissioners or water masters, as they are sometimes called on the various streams. The division superintendents are usually appointed by the Governor. The only serious objection to the system as adopted in the various states has been the payment of water commissioners by the counties, the cost of assessing and collecting the amounts from the water users being relatively very large and the procedure involving much delay. The central offices of practically all of the thirteen states where this system is in effect condemn it and recommend payment by the state instead.

Proposed Legislation.

To provide for necessary administrative machinery to undertake the distribution of water, a bill has been prepared by the Commission embodying the best features of similar laws in other irrigation states. The bill, which appears in full in the Appendix, provides for the division of the state into water districts as necessity arises, and the appointment of water masters by the State Water Commission. It specifies that the duty of a water master under the direction of the Commissioners is to divide the waters of a stream among the various diversion conduits and reservoirs taking water therefrom, according to the relative rights of the water users. It authorizes the regulation of canal headgates and controlling works of reservoirs, and provides means for the enforcement of regulations. It also authorizes the Commission to compel the construction of headgates and diversion works where necessary.

CHAPTER V.

ARBITRATIONS.

San Diego River.

Under an agreement not yet fully consummated by all the land owners, the Commission has agreed to act as arbitrator to fix damages that might accrue from storage on the San Diego River proposed at or near the diversion dam of the old San Diego Flume now owned by the Cuyamaca Water Company. The land owners in the Cajon Valley along the river below the El Capitan dam site derive their irrigating supplies from the detrital fill in the river and wish to be protected against loss of their supply, and are desirous at the same time of having the reservoir built as a protection against a recurrence of the flood losses inflicted by the 1916 floods.

Bishop Creek.

In this case, Commissioner A. E. Chandler was selected by the water users, Southern Sierras Power Company and city of Los Angeles, to settle vexatious questions regarding the release and use of waters stored in upper reaches of Bishop Creek for use through the power plants. The complete settlement of these questions has been left with Mr. Chandler, who has since resigned, and these matters are now under adjustment.

CHAPTER VI.

SPECIAL INVESTIGATIONS.

Under the terms of the Water Commission Act, the Commission is authorized under section 40 as follows:

The State Water Commission is also authorized and empowered to investigate any natural situation available for reservoirs or reservoir systems for gathering and distributing flood or other waters not under beneficial use in any stream, stream system or lake or other body of water, and to ascertain the feasibility of such projects, including the supply of water that may thereby be made available, the extent and character of the areas that may be thereby irrigated, and make estimate of the cost of such project.

The Commission has had many urgent requests for such investigations, but has been compelled to refuse them in a number of cases that were justified, because of lack of funds for which adequate provision was not made by the Legislature. In spite of this handicap, much important work has been done either with money supplied by the people themselves, or in cooperation with them, other State departments and county officials. At the present time several studies of very considerable importance are under way, among which are:

Kings River.

This was commenced in December, 1917, and involved a comprehensive and systematic measurement of all ditch diversions from Kings River, one of the largest irrigation streams in the state. The work was undertaken at the request of the Kings River Conservation District Association to assist in the definition of all existing water rights on the stream preparatory to the construction and operation of a large storage reservoir at Pine Flat. The work has been carried on during three full irrigation seasons by Charles L. Kaupke, engineer in charge. A fuller report appears in Appendix G. Funds for carrying on the work during the first two years were derived partly from the Water Commission appropriation, and partly from local sources. During the past season local interests have supported the entire work.

An interesting outgrowth of the work has been a voluntary agreement among ditch interests to a schedule of diversions covering a partial range of flow of the river and placing the distribution of the waters in accordance therewith in the hands of a water master appointed by the State Water Commission, further reference to which will be found in Chapter IV.

Kern River.

A complete study has been undertaken of the storage, power and ground water possibilities of this stream with a possible reapplication or absorption of the vested rights in the normal flow into one system

that will provide for the fullest utilization of this supply both for agriculture and power. This study is being carried out under the personal supervision of Professor S. T. Harding, of the State University (a more complete synopsis of which is printed in Appendix C of this report), under cooperation between the State Water Commission, the State Engineer, board of supervisors of Kern County, Kern County Farm Bureau, Kern County Land Company, Tejon Ranch Company, and other land owners. If a feasible and practicable plan can be worked out and be accepted by the holders of vested rights, a large area of additional acreage can be put under water and a very considerable addition to power development can be made. It is expected that the investigation will be ready for report about January 1, 1921.

San Joaquin River.

In this case, it was found that in order to determine whether an extension of the application of the water supply was practicable and feasible, a careful study of the situation was necessary. Much uncertainty exists as to the extent of the rights of large land holders in the locality, as well as to the possibilities from the watershed. In order that such investigation might be impartial as to claimants, the Commission was requested by the Madera Irrigation District to undertake this investigation with the understanding that the findings were to become the property of the public, and an agreement to this effect was entered into in June, 1920. The study is now being carried on under the charge of Harrison Smitherum, Engineer of the Commission. A detailed statement covering the progress of this study will be found in Appendix H of this report.

Inyokern Irrigation District.

In this valley the settlers have made considerable progress in the development of their lands from the available ground water supply. The great area of the valley, estimated at 92,000 acres, available for irrigation, has led to an effort to secure an additional supply of water sufficient to bring the whole area under a gravity system. They first filed upon the head waters of Kern River, but abandoned this source as impracticable, and later filed on the water supply of the Mono Lake Basin, with the purpose of tunneling through the rim of the basin to the eastward and utilizing the storage site available at Black Lake; thence, transporting the water southward paralleling the Owens River and Los Angeles aqueduct system to their lands, an approximate distance of two hundred miles. In this plan they expect to cooperate with the Southern Sierras Power Company in power developments along their transmission ditches that will reduce the cost to them of this supply. The courage and enterprise of these people exceeds that of the Los Angeles aqueduct enterprise. They have carried on at considerable

expense earlier investigations and have recently taken steps to form an irrigation district for the purpose of organization and raising among themselves the necessary money to prove whether or not the plan is feasible. They have by their enterprise, secured active support from the board of supervisors of Kern County, which has appropriated $1,500 to assist them in the study of the situation, and the officers of the Kern County Farm Bureau are actively assisting the settlers to effect the organization. An agreement between the State Water Commission and the Kern County Farm Bureau is now being prepared under which the study will be supervised by the Commission and carried on by an engineer of its selection.

Salinity Investigations in the Delta of the Sacramento and San Joaquin Rivers.

The dry seasons of the past several years, coupled with the rapid increase of irrigation, both in the delta and along the upper Sacramento and San Joaquin, brought about a very low stage in the flow of these streams, and salt infiltration from tidal action penetrated far up into the delta region, causing much apprehension to these land owners and the cities and towns depending upon these rivers for their domestic requirements.

The possibility of the advance of salt water from San Francisco Bay into the delta of the Sacramento and San Joaquin Rivers was discussed in the 1917 report of the State Water Commission, and preliminary observations were made in October, 1916, to determine the degree of salinity at that time. Two other series of measurements were made in 1919. The unprecedented drought culminating in 1920 with low stream flow, coupled with greatly increased irrigation use, made it apparent early in the year that salinity would reach further into the delta than in previous years. The Commission took steps early in February to give widespread publicity throughout the Sacramento Valley of the impending situation, to the end of reducing as far as possible the acreage planted in rice which requires late irrigation to mature. This effort, combined with that of other public agencies, resulted in at least 50,000 acres being withheld from planting.

The State Water Commission, in cooperation with the State Department of Engineering, also initiated a systematic investigation of salinity conditions throughout the delta, gathering water samples at high and low tide daily or every other day at strategically located stations, and analyzing them for salinity. This work was started in May, and has continued throughout the season, in charge of Glenn V. Rhodes as engineer for the Commission. A report describing the work in detail and giving interesting diagrams showing the variation of salinity at different times at the various stations will be found in Appendix D. The work was financed partly by the State Department of Engineering

and the State Water Commission, and partly by local land owners in the delta. Much data has been gathered during the season's investigation, which will be of value in working out the solution of the salinity problem in the delta.

As an outcome of these conditions on the river, an action has been brought by the city of Antioch asking for an injunction against diversions by all of the upper users on the river. Because of the legal principles involved, this action is one of very great importance as related to the future utilization of the remaining unused water resources of the state. The case is now on trial and the outcome is awaited with great interest by those interested in these matters.

Land Settlement Board.

Under section 9 of chapter 755, Statutes of 1917, known as the "Land Settlement Board Act," the President of the Water Commission has been called upon to "certify in writing as to the sufficiency of any water rights to be conveyed"; and under this provision has been called upon to pass upon the water supply of three tracts selected by the Land Settlement Board.

The Durham Farm, comprising 6219 acres and depending upon the flow of Butte Creek for its water supply, was the first to be submitted.

The James Ranch in Fresno County, including approximately 3200 acres, was also investigated, and exhaustive pumping tests of wells were made to determine the sufficiency of the underground water supply.

The Wilson Tract, of about 7000 acres, lying north of the Merced River on the Southern Pacific and Santa Fe railroads, has also been under investigation. The Durham and Wilson tracts have been purchased by the Land Settlement Board.

Water Supply for State Institutions.

On several occasions the State Water Commission has been called upon by the State Board of Control for advice regarding water rights as they affect the water supply at state institutions under the supervision of the board. Investigations were made by the Engineering Department of the Commission in each case, and report transmitted to the Board of Control. In addition, conferences took place to discuss many complex features regarding water rights. The investigations made during the past two years were as follows:

Water supply for the Sonoma State Home at Eldridge, Sonoma County.

Water supply for California Polytechnic School at San Luis Obispo.

Water supply for Whittier State School at Whittier.

In each instance, more or less investigation of local water rights was made, as well as measurements of water and study of the physical situation.

CHAPTER VII.

COOPERATIVE WORK.

In addition to the cooperative undertakings spoken of heretofore in this report, many other matters have had the support and assistance of the Commission in the public interest. While it is generally recognized as the duty of the state and federal governments to collect and assemble rainfall and runoff data, a large amount of the available data now collected has been gathered by private concerns, or in cooperation with state or federal officers. As irrigation, power, flood, highway and harbor problems become more pronounced and vital to the public interest, the need of such information, which to be valuable should extend over a considerable period of years, becomes more and more apparent. The cooperative idea, where it is being put into practice, is demonstrating the efficiency and practicability of this method. This is being demonstrated in a considerable number of studies now being carried on in California under some form of cooperation.

United States Geological Survey.

The Water Resources Branch of the United States Geological Survey is the branch of this service entrusted with the duty of collecting stream flow and runoff data that is essential in determining the water supply that may be depended upon either from the normal flow or from floods on a stream system or river. This information is fundamental for the laying out of any hydraulic project, and upon it engineers must rely in preparing plans and estimates. At the present moment, when storage for agriculture and hydro-electric enterprises has become of such economic importance, the scarity of reliable data of this sort is keenly felt in all parts of the state, and is also greatly needed by the Commission in the consideration of applications for a water supply for new projects. The Survey being already established and receiving the support of the State through the State Department of Engineering, the Commission instead of attempting to duplicate the work of the Survey, has actively cooperated with the office and supplied it with funds to assist it in maintaining and extending its operations. Special studies have also been undertaken by the Survey in a number of cases, at the request of the Commisson, and data of great value and usefulness has been supplied. A special report covering this work by the Survey is printed elsewhere in Appendix I.

Two most interesting illustrations of this work are being carried on in Los Angeles County and along the Santa Ana River.

PLATE VIII.
GAGING STATIONS IN SANTA ANA DRAINAGE.

Devil Canyon Creek near San Bernardino, California.

City Creek near Highlands, California.

LOS ANGELES COUNTY AND SANTA ANA RIVER STUDIES.

In Southern California, where the water supply is very restricted and the available waters find their highest duty, such data has been found very needful for extensions of the water resources, conservation of flood runoff in surface and underground reservoirs and in flood control undertakings of larger magnitude.

In Los Angeles County, $4,500,000 was voted in bonds to furnish flood protection after the heavy floods of 1914 and 1916. The United States Forest Service was also interested in a study upon the effect of brush cover on the runoff from the mountain watershed. Through public interest in these matters a cooperative agreement, which the Commission assisted in bringing about, was entered into between the Forest Service, United States Geological Survey, United States Weather Bureau and Los Angeles County, under which fifteen permanent reinforced concrete gaging stations equipped with automatic stage recording devices were installed on every mountain stream of consequence flowing into the San Fernando and San Gabriel Valleys from the Sierra Madre Range. In addition to this, about sixty standard United States rain gages were established in the mountains under the direction and supervision of the United States Weather Bureau. The stream gages were installed and operated by officers of the Forest Service and the United States Geological Survey, and already data of the greatest importance has become available to the public from these records.

The Santa Ana River, rising in the San Bernardino Mountains, furnishes water for power and for the irrigation supply of one of the richest areas in the state. It flows through the three counties of San Bernardino, Riverside and Orange, and the waters after being collected in Big Bear Reservoir on the top of the range at seven thousand feet elevation are used most intensively from this point to the ocean. The larger irrigation enterprises had been carrying on effective conservation work for a number of years through mutual efforts, and an organization known as the Tri-Counties Reforestation Association. Flood problems also demanded immediate attention to prevent great damage to the extremely valuable lands lying in the path of floods. The need of reliable data was as apparent here as in other sections. Indeed little of real value existed, and after considerable effort and negotiation, the Los Angeles County agreement was duplicated with some modifications and the installation of a complete system of permanent gaging stations was begun with an appropriation of $1,000 from each of the three counties. At the 1919 session of the Legislature, the Water Commission requested an appropriation by the state to be expended in completing these stations, on the condition that the counties would provide a continuous annual appropriation of $1,000 each for maintenance and extensions. The state appropriation was secured and fourteen gaging stations were completed within the estimate during the war period by

the officers of the United States Geological Survey, and since then several important additional stations have been put in. Rain gages were installed on the San Bernardino watershed by the United States Weather Bureau, among which are two of the new Marvin type of self-recording instruments, which record the intensity and duration of the precipitation as well as the amount. These studies bid fair to become of the greatest economic importance to the main citrus and walnut growing regions of the South, and also demonstrate the effectiveness of rational cooperation between the water users and the state.

SAN DIEGO RIVER.

A similar study has been provided for on the San Diego River whereby the United States Geological Survey agrees to gather the necessary runoff and ground water data at the direction of the Commission and at the expense of the Cuyamaca Water Company under the terms of an agreement permitting of the storage of flood waters by the company.

Emergency Water Conservation Conference.

Early in the year 1920, the extraordinary prices received by the rice growers in the Sacramento Valley stimulated a very great interest in rice growing, and it became apparent that if the rainfall was again below normal that serious losses and great conflict over the water supply would ensue. It was estimated that over 200,000 acres were being prepared for this crop. Warnings were sent out by the Commission urging caution in the plans for planting upon the indications of a shortage in rainfall. As the season progressed and it became more and more apparent that the water supply would be abnormally low in the Sacramento River, additional steps were taken to warn prospective water users and conferences were held in the rice-growing areas. At the instance of the Governor, the water users of the Sacramento River above Sacramento City were called together in San Francisco and after much negotiation, the Emergency Water Conservation Conference, consisting of the members of the State Water Commission, the Railroad Commission, the State Engineer, and various other state and federal officers was formed to carry out under agreement between the water users the regulation of diversions and use of the supply. An executive committee composed of E. O. Edgerton, President, and C. H. Loveland, Hydraulic Engineer of the Railroad Commission, A. W. Mason and W. A. Johnstone, members of the State Water Commission, and State Engineer W. F. McClure, were appointed by the conference to be in active charge of the work.

The Executive Committee selected Paul Bailey from the Water Commission engineering staff as water master, and levied an assessment upon the members of the conference for the purpose of meeting its expenses. At the outset, the members of the Executive Committee

traveled over the area with members of the conference and its water master, and as soon as the rice-growing season was begun, the latter had organized his force of assistants and established his headquarters at Colusa. The work of the water master was one of extreme delicacy and of heavy responsibility. As the season progressed, it became apparent that the acreage must be materially reduced, and on the data shown by him, his recommendations were agreed to and a maximum crop for the water available was matured with no serious conflict. The work was accomplished on about one-half of the estimated cost so that nearly fifty per cent of the assessment will be refunded when the work is closed up. The members of the different departments concerned feel much satisfaction with the showing made. Without some such effort there would have been a most serious reverse, if not a disaster to the rice industry, for otherwise a very large amount of litigation would have promptly ensued with an impossibility of maintaining an economic use of the water available under such conditions. Further reference is made in a report by the water master in Appendix J.

United States Department of Agriculture, Bureau of Public Roads.

Cooperation with this department has been confined to investigations in connection with the use of water in irrigation. This Department is well equipped to carry on investigational work of this type, and the funds made available to it by the State Water Commission could not be expended to greater advantage.

DUTY OF WATER IN RICE CULTURE.

During the biennial period closing June 30, 1920, the five-year investigation of use of water in rice culture in the Sacramento Valley, described in previous reports of the Commission, was completed. The Commission has assisted in this work to the extent of $3,690.* The results of this work are described in detail in another chapter of this report.

USE OF WATER FROM KINGS RIVER.

A special study of the use of water from Kings River in connection with measurements of canal diversions carried on by the State Water Commission has also been finished and is treated more fully in another place in this report. Both of these investigations have been made available for use in the form of published reports.°

* Bulletin No. 325, University of California Agricultural Experiment Station, Rice Investigation Measurements and Experiments in Sacramento Valley, 1914–1919. By Frank Adams.

° Bulletin No. 7, State Department of Engineering, Use of Water from Kings River, Cal., 1918.

NEW IRRIGATION MAP.

The Commission is assisting financially to the extent of $1,000 in the revision of the irrigation map of California published in 1912 by the Office of Experiment Stations, United States Department of Agriculture, in cooperation with the California Conservation Commission. Much additional information will be shown upon it, including a revision of the irrigated area, boundaries of irrigation districts, location of United States Geological Survey gaging stations, important hydroelectric power developments, large reservoirs in operation, and other general information, all of which will greatly increase the usefulness of the map.

State Department of Engineering.

Among state offices, the Water Commission has closest contact with the State Department of Engineering. The cooperation of the two offices includes the investigation of sufficiency of water supply of irrigation districts where water rights are being initiated under the Water Commission Act, rendering of opinions by the Commission upon the extent of undefined water rghts of irrigation districts contemplating bond issues; notification by the Commission when applicants for appropriations contemplate construction of dams whose supervision is under the authority of the State Engineer, and making of general water resource investigations. Among the latter, the most important now in progress are the Kern River investigations initiated early in 1920 in connection with the proposed Kern River Irrigation District, which are described in detail in Appendix C of this report; the Kaweah and Tule River investigations commenced in the summer of 1920, which include a thorough study of underground waters in Tulare County and the investigations of salinity encroachment into the delta of the Sacramento and San Joaquin rivers from San Francisco bay. The latter is described in detail in the Appendix. These investigations are being carried on partly with state funds and partly with funds furnished locally. Much original data is being gathered, and the results should throw much light on local water problems and lead to constructive progress in utilization of the available water resources.

One branch of the State Engineer's work which is of particular value to the Water Commission is the systematic measurement of flow of the Sacramento River at various points and the irrigation diversions therefrom, which has been carried on during the past two seasons. The great majority of projects diverting from the Sacramento River are under permit to appropriate water issued by the Water Commission, and these measurements make available to the Commission, data which otherwise would have to be obtained independently at greater expense to the state.

The investigations carried on in cooperation with the State Engineer, other than that on Kaweah and Tule Rivers, are described elsewhere in this report and need not be repeated here.

KAWEAH AND TULE RIVER INVESTIGATION.

This investigation covers a thorough study of the underground water resources of Tulare County and is being made by the State Department of Engineering under the direction of Professor S. T. Harding, Irrigation Department, State University. It was begun at the request of Tulare Water Users' Association and other water users in the county during the summer of 1920. A request was made to this office to undertake this study, but because of lack of money, the Commission was unable to do so. However, it has taken an active interest in it, and has lent its assistance in conference with other departments in working out the general plan adopted for the study.

CHAPTER VIII.

FEES AND ADMINISTRATIVE COST.

Applications to Appropriate Water.

The fees collected under the terms of the Water Commission Act are nominal in amount, and are less than those charged by neighboring states. Prior to the amendment to the act which became effective July 27, 1917, the fees were greater, especially in the case of the generation of electrical energy.

The total amounts collected in fees for applications for water rights (including permit fees) each fiscal year since the organization of the Commission are as follows:

1914-1915 (3 months)	$ 1,410 10
1915-1916	7,566 08
1916-1917	10,261 80
1917-1918	4,157 73
1918-1919	3,999 55
1919-1920	6,769 76
Total	$34,165 02

The amendment has resulted in reducing these fees collected by approximately 40 per cent. The act provides that all fees collected shall be paid into the State Treasury.

The cost of the work done by the Water Commission in the supervision of the appropriation of water for each fiscal year since the organization of the Commission is as tabulated below. The amounts can be approximately segregated into the items "Engineering" 41 per cent; and "Administration" 59 per cent. The latter includes two-thirds of the Commissioners' salaries. The salaries of the three Commissioners prior to the change in the act July, 1919, was $15,000 per annum. Under the reorganization, the total for the fiscal year 1919–1920 has been $10,203.02, a reduction of about $5,000 per annum.

The total amount of expenditures on applications by fiscal years are as follows:

1914-1915	$ 7,458 59
1915-1916	35,330 43
1916-1917	53,734 41
1917-1918	37,101 00
1918-1919	42,468 00
1919-1920	36,115 00

Comparison of these figures with corresponding receipts from fees shows that the latter vary from 10 to 20 per cent of the amount expended from appropriations. The fees at present charged under the act for supervision of appropriation of water are far from sufficient to reimburse the State for this phase of the Commission's work.

The volume of work handled during the above six fiscal years is indicated by the fact that final action was taken upon applications representing 2,418,400 acres of irrigable land and 1,111,000 horsepower of electrical energy. In addition, much work was done on pending applications and in inspection of construction and use of water under permits.

Adjudications.

The fees to be collected from claimants at the time of submission of proofs and paid into the State Treasury as provided by statute, are as follows:

For irrigated or irrigable land
- 0 to 100 acres ---------- 15 cents per acre
- 101 to 1000 acres ---------- 10 cents per acre
- 1001 or more acres ---------- 5 cents per acre

For electrical energy generated
- 0 to 100 theoretical horsepower ---------- 25 cents per theoretical horsepower
- 101 to 1000 theoretical horsepower ---------- 10 cents per theoretical horsepower
- 1001 or more theoretical horsepower ---------- 5 cents per theoretical horsepower
- Other uses ---------- $5.00 per cubic foot per second

Minimum fee for any use, $5.00.

The total fees collected from claimants in the Stanislaus River adjudication were $14,494.21. The cost to the Commission of surveys, preparations of maps and data, hearings, etc., has been approximately $11,000. This amount is $3,500 less than the fees paid into the State Treasury. The cost was less for this work than ordinarily would be the case, as accurate maps were available for most of the land. There were 131,865 acres of irrigable land and 40,000 horsepower developed electrical energy involved in this adjudication.

The West Carson River adjudication has not been completed yet, but an estimate of the fees which are to be paid is approximately $570. The cost of surveys, etc., when completed, will be close to $2,400. The lands are in small tracts scattered along the stream at intervals, and the cost of surveys per acre is greater than is the case where the land lies in large bodies. The total area involved is 4998 acres of irrigated land.

Although the total fees paid in these two adjudications will exceed the total cost, yet in view of the number of small streams in the state corresponding more or less with the West Carson River, a readjustment of fees charged for stream adjudications is recommended which will bring about a more equitable division between the state and water users of the cost of necessary hydrographic surveys.

PLATE IX.

Eagle Lake, the proposed source of supply for the Baxter Creek and Tule Irrigation Districts.

CHAPTER IX.

IRRIGATION ACT DISTRICTS.

Under this recently created act a number of districts were proposed and considerable headway was made in this direction until the Supreme Court of the State in *Geo. Mordecai et al.* vs. *Board of Supervisors of the County of Madera et al.*, held that the act was unconstitutional because of the exemption of certain counties in its application. Active steps are under way to submit another bill or bills carrying the needful provisions without the sections that caused the act to fail. The act in brief permitted the combination of districts or other agencies for the purpose of reservoiring and distributing large quantities of flood waters in reservoirs that were too great and costly for the ordinary project to handle, or where for practical reasons it became necessary to combine the existing districts or companies in the undertaking. The act also provided a means for state and federal cooperation, legal machinery for which was theretofore lacking.

The two most prominent undertakings which were expecting to organize under the act were the Iron Canyon Reservoir Project on the Sacramento River near Red Bluff, and the Pine Flat Reservoir on Kings River above Fresno, for each of which applications are pending before this office.

There were 17 petitions for organization of irrigation districts filed under this act and one petition for formation of a conservation district, that of the Pine Flat. Of the 17 petitions for irrigation districts, five were approved by the Board and orders issued creating the districts.

The following is a list of petitions for irrigation districts filed and approved under this act:

Name	County	Area, acres
Medana Irrigation District	Madera and Merced	13,560
San Jose Irrigation District	Kings	25,597.3
Tulare Lake Irrigation District	Kings	161,720
Mendota Irrigation District	Fresno	87,118.79
Colusa-Delta Irrigation District	Colusa, Sutter and Glenn	22,729.47

PLATE X.

Musselbeck Dam constructd by Happy Valley Irrigation District.

PLATE XI.

Site of proposed Don Pedro Dam on Tuolumne River to be constructed by Modesto and Turlock Irrigation District for storage of 300,000 acre-feet of water annually.

CHAPTER X.

IRRIGATION DISTRICTS OF CALIFORNIA.

The activity in agricultural development during the past two years has resulted in the initiation and organization of many new irrigation districts under the Irrigation District Act, popularly known as the Wright Act. This act, with various amendments, has been on the statute books in its present form since 1895 and is the one under which all the existing irrigation districts of the State are organized. Since the Irrigation Act was declared unconstitutional by the Supreme Court, most of the districts initiated or organized under the latter act have taken steps to reorganize under the old act.

At the present time, there are sixty-eight Wright Act districts in the state, of which twenty-five were organized during the past two years. Among the larger districts recently organized are the Madera Irrigation District, with 350,000 acres, the Merced with 200,000 acres, Glenn-Colusa with 103,000 acres, the Honcut-Yuba with 50,000 acres, and the Corcoran with 48,000 acres. Other large districts proposed are the Iron Canyon with 300,000 acres, Kern Delta with 400,000 acres, Klamath-Shasta Valley with an area exceeding 100,000 acres, the Mendota with 87,000 acres, the Suisun with 41,000 acres, the West San Joaquin with 208,000 acres, and the Yolo with 50,000 acres.

The following table lists the irrigation districts, both organized and proposed, which have permits issued or applications on file with the Water Commission for appropriation of water. The applications of proposed districts are usually filed in the name of an individual as trustee, but have been listed here under the name of the proposed district:

TABLE 10.

Irrigation Districts Having Applications for Appropriation of Water on File with the State Water Commission as of December 16, 1920.

Name	Application number	Permit number	County	Source	Amount applied for—irrigation		Acreage
					Second-feet	Acre-feet	
Anderson-Cottonwood	12*-916		Shasta	Sacramento River	400		32,000
Banta-Carbona	1,933		San Joaquin	Salmon and Old Rivers	250		20,000
Baxter Creek	208	783	Lassen	Eagle Lake		30,000	12,500
Baxter Creek	1,209	782	Lassen	Eagle Lake		30,000	12,500
Beaumont	1,837		Riverside	Edgar and Noble Creeks	8		2,500
Big Valley	1,073		Modoc	Ashoe Creek		67,000	47,000
Brown's Valley	12*-1,986		Yuba	North Yuba River	62.50		40,000
Brown's Valley	1,967		Yuba	Little Oregon Creek		50,000	11,500
Brown's Valley	1,995		Yuba	North Yuba River	25		40,000
Canejo (proposed)	1,831		Ventura	Sespe and Piru Creeks	Power		
Canejo (proposed)	1,832		Ventura	Sespe and Piru Creeks	200	150,000	10,800
Carmichael	138	67	Sacramento	American River	15		3,100
Carmichael	1,611		Sutter	Feather River	30		1,593
Conchow-Table Mountains (proposed)	1,739		Butte	Conchow Drainage	50	20,000	8,000
Crooks Canyon	1,657		Modoc	Crooks Canyon		9,617	4,019
East Side	512	358	Siskiyou	Scott River	100		5,600
Fall River Valley (proposed)	1,467		Shasta	Fall River	250		20,000
Feather River	1,627		Sutter	Feather River	38		8,000
Foothill	2,042		Fresno	Kings River	300		57,000
Glenn-Colusa	1,948		Shasta	Pit and Fall Rivers		1,000,000	500,000
Greenfield (proposed)	2,032		Monterey	Arroyo Seco		50,000	7,500
Greenfield (proposed)	2,033		Monterey	Arroyo Seco		40,000	7,500
Grass Valley (proposed)	1,735		Nevada	Bear River	175	65,000	22,000
Grass Valley (proposed)	1,736		Nevada	Yuba River	150	5,400	
Happy Valley	782	531	Shasta	Ducket Creek		1,166	18,000
Happy Valley	783	532	Shasta	North Fork Cottonwood Creek		740	18,000
Happy Valley	784	533	Shasta	North Fork Cottonwood Creek		5,700	18,000
Happy Valley	1,774		Shasta	North Fork Cottonwood Creek	75		18,110
Honcut-Yuba	1,133		Yuba	Yuba River	500		25,000
Honcut-Yuba	1,216		Butte	Feather River	1,000		50,000
Honcut-Yuba	1,275		Yuba	Yuba River	500		50,000
Honcut-Yuba	1,646		Butte	North Honcut, South Honcut and Wyandotte Creeks		100,000	30,000
Honcut-Yuba	1,688		Yuba	Indiana Creek		100,000	30,000

*Application filed under Sec. 12 of the Act.

Honcut-Yuba	1,689		Yuba	Dry Creek		100,000	
Honcut-Yuba	1,795		Yuba	Dry Creek		65,000	27,800
Hot Springs Valley	1,360		Modoc	Big Sage Drainage		77,000	9,600
Inyokern	1,274		Mono	Rush Creek, Leevining Cr., etc.	1,275	500,000	87,000
Iron Canyon (proposed)	1,279		Tehama	Sacramento River	2,500	775,100	306,000
Iron Canyon (proposed)	1,280		Tehama	Sacramento River	Power		
Iron Canyon (proposed)	1,841		Tehama	Thoms Creek	750	125,000	50,000
Iron Canyon (proposed)	1,842		Tehama	Elder Creek	600	100,000	40,000
Iron Canyon (proposed)	1,843		Tehama	Red Bank Creek	400	75,000	30,000
Iron Canyon (proposed)	1,844		Tehama	Cottonwood Creek	250	75,000	30,000
Iron Canyon (proposed)	1,845		Tehama	Sacramento River	670		300,000
Jess Valley	1,080		Modoc	South Fork Pit River	524		40,000
Kern Delta (proposed)	1,547		Kern and Tulare	Kern River	Power		
Kern Delta (proposed)	1,548		Kern and Tulare	Kern River		1,500,000	400,000
Knightsen	1,718		Contra Costa	Indian Slough and Marsh Creek	200		9,000
Klamath-Shasta Valley (proposed)	1,959		Siskiyou, Cal., Klamath, Ore.	Klamath River	1,500	1,000,000	197,000
Klamath-Shasta Valley (proposed)	1,996		Siskiyou, Cal.	Shasta River	Power		
Klamath-Shasta Valley (proposed)	2,075		Siskiyou, Cal., Klamath, Ore.	Klamath River	Power		
Klamath-Shasta Valley (proposed)	2,149		Siskiyou, Cal., Klamath, Ore.	Klamath River	410	150,000	40,000
Lindsay-Strathmore	948		Tulare	Kaweah River	75		15,000
Little Rock Creek	912	476	Los Angeles	Little Rock Creek		7,650	2,857
Long Valley	401		Lassen	Long Valley Creek	550	55,000	30,000
Long Valley	495		Sierra	Little Truckee River	100	55,000	30,000
Long Valley	820		Sierra	Little Truckee River	50	55,000	30,000
Long Valley	2,016		Lassen	Long Valley Creek		20,000	4,300
Lookout-Bieber (proposed)	1,792		Modoc	Pit River		75,000	35,000
Madera	234		Madera, Fresno	San Joaquin River	3,000	500,000	353,000
Madera	797		Madera	Fine Gold Creek		135,700	300,000
Madera	1,465		Madera	San Joaquin River	5,000	1,150,000	350,000
Madera	1,496		Madera	Fresno River	250	150,000	10,000
Madera	1,945		Mariposa	South Fork Merced River	2,500	100,000	120,000
Madera	1,946		Mariposa	Big Creek	2,500	100,000	
Madera	1,973		Madera	Chowchilla River	500	60,000	31,400
Madera	1,974		Merced	Chowchilla River	500	60,000	
Maxwell	18	29	Colusa	Sacramento R. & Colusa Basin	125		4,700
Maxwell	186	72	Colusa	Sacramento R. & Colusa Basin	130		5,240
Maxwell	598	341	Colusa	Sacramento River	160		5,670
Maxwell	901	482	Colusa	Sacramento River	100		3,977
Medano (proposed)	1,197		Madera, Merced, Mariposa	Chowchilla River		60,000	13,560
Medano (proposed)	1,513		Madera, Merced, Mariposa	Chowchilla River		60,000	13,560
Mendota (proposed)	1,470		Fresno	Fresno Slough	400	100,000	87,118
Merced	1,221		Mariposa	Merced River	Power		

TABLE 10—Continued.

Irrigation Districts Having Applications for Appropriation of Water on File with the State Water Commission as of December 16, 1920.

Name	Application number	Permit number	County	Source	Amount applied for—irrigation		Acreage
					Second-feet	Acre-feet	
Merced	1,222		Mariposa	Merced River	Power		
Merced	1,224		Merced	Merced River	2,500	700,000	200,000
Merced	1,473		Merced	Merced River	2,500	600,000	180,000
Merced	1,722		Merced	Burns Creek		120,000	173,000
Merced	1,723		Merced	Black Rascal Creek		80,000	173,000
Merced	2,062		Merced	Burns Creek	1,000		200,000
Modesto	1,259		Tuolumne	Tuolumne	Power		
Modesto	1,456		Tuolumne	Tuolumne River		600,000	100,000
Modesto	1,569		Tuolumne	Tuolumne River	Power		
Mojave River	438		San Bernardino	Deep Creek and West Fork Mojave River	120	100,000	26,878
Oakdale	77		Tuolumne and Alpine	Highland Creek		62,836	74,146
Oakdale	504	242	Stanislaus	Stanislaus River	20		4,074
Oakdale	1,061		Calaveras and Tuolumne	Stanislaus River		96,195	74,246
Oakdale	1,157	775	Calaveras	North Fork Stanislaus River	Power		
Oakdale	1,214		Calaveras	Stanislaus River	130	31,957	74,246
Oakdale	1,424		Calaveras	Little John's Creek		100,000	143,000
Oakdale	1,425		Calaveras	Black Creek	Power		
Oakdale	1,426		Calaveras	Little Johns Creek		100,000	143,000
Oakdale	1,427		Calaveras	Black Creek		46,000	143,000
Oroville-Wyandotte	1,651		Plumas	South Fork Feather River	5,000	300,000	20,000
Oroville-Wyandotte	1,931		Butte	Fall Creek	500	100,000	20,000
Oroville-Wyandotte	1,932		Plumas	Slate Creek		100,000	
Paradise	92		Butte	Little Butte Creek		6,600	11,100
Paradise	93		Butte	Long Gulch		3,500	11,100
Paradise	476	271	Butte	Little Butte Creek		19,600	11,100
Princeton, Codora, Glenn	244	463	Glenn	Sacramento River	120		8,000
Princeton, Codora, Glenn	770	464	Glenn	Sacramento River	120		7,500
Provident	462	303	Glenn	Sacramento River	250		14,123
Provident	892	416	Glenn	Sacramento River	110		7,609
Provident	1,376		Glenn	Deer Creek	Power		
Red Rock Creek	188		Lassen	Red Rock Creek	6	80	160
Red Rock Creek	1,141		Lassen	Red Rock Creek		7,500	3,240
Roseville (proposed)	2,026		Placer	Miner's Ravine		20,000	15,500

San Jose (proposed)	1,362		Fresno-Kings	Kings River	500	45,000	45,000
Santa Clara Valley (proposed)	2,103		Santa Clara	Arroyo Calero	30	8,000	150,000
Santa Clara Valley (proposed)	2,104		Santa Clara	Llagas Creek	50	15,000	150,000
Santa Clara Valley (proposed)	2,105		Santa Clara	Uvas Creek	80	25,000	150,000
Santa Clara Valley (proposed)	2,106		Santa Clara	Almaden Creek	30	6,000	150,000
Santa Clara Valley (proposed)	2,107		Santa Clara	Coyote R. and Los Animas Cr.	200	120,000	150,000
Santa Clara Valley (proposed)	2,136		Santa Clara	Calabazas Creek	20	1,500	150,000
Santa Clara Valley (proposed)	2,137		Santa Clara	Guadalupe Creek	50	6,000	150,000
Santa Clara Valley (proposed)	2,138		Santa Clara	Stevens Creek	50	7,000	150,000
Scott Valley	512	358	Siskiyou	Scott River	100		5,600
Southern Lassen	85		Lassen	Red Rock Creek		15,000	22,565
Southern Lassen	85a		Plumas	Last Chance Creek	150	19,250	22,565
Southern Lassen	85b		Lassen	Long Valley Creek	300	100,000	22,565
South San Joaquin	1,424		Calaveras	Little John's Creek		100,000	143,000
South San Joaquin	1,425		Calaveras	Little John's Creek	Power		
South San Joaquin	1,426		Calaveras	Little John's Creek	Power		
South San Joaquin	1,427		Calaveras	Black Creek		46,000	143,000
South San Joaquin	1,446		San Joaquin	Stanislaus River	150		15,000
South Feather (proposed)	1,608		Butte	South Fork Feather River		50,000	30,000
Suisun (proposed)	1,297		Solano	Lindsay Slough	400		41,076
Surprise Valley	579		Modoc	Cowhead Lake, Twelve Mile Creek, Rock and Horse Orks.	575	115,000	18,925
Terra Bella	32		Tulare	Deer Creek		25,000	12,500
Terra Bella	1,796		Tulare	Deer Creek		20,000	12,500
Tulare Lake (proposed)	353		Kings	Kings River	2,000	300,000	138,543
Tulare Lake (proposed)	354		Kings	Kern River	1,000	200,000	138,543
Tulare Lake (proposed)	355		Kings	Tule River and Kaweah River		150,000	
Tule	208	783	Lassen	Eagle Lake		30,000	12,500
Tule	1,209	782	Lassen	Eagle Lake		30,000	12,500
Turlock	1,232		Tuolumne	Tuolumne River	Power		
Turlock	1,233		Tuolumne	Tuolumne River		600,000	200,000
Turlock	1,442		Merced	Merced River	94		7,664
Turlock	1,582		Tuolumne	Tuolumne River	Power		
Vernalis	1,609		San Joaquin	San Joaquin River	100		8,356
Walker River	1,388		Mono	Murphy Creek		10,000	
Walker River	1,389		Mono	East Walker River		80,000	
Walker River	1,390		Mono	Green Creek		25,000	
Walker River	1,391		Mono	Robinson Creek		25,000	
Walker River	1,392		Mono	Summers Creek		10,000	
Walker River	1,393		Mono	Swager Creek		10,000	

TABLE 10—Continued.

Irrigation Districts Having Applications for Appropriation of Water on File with the State Water Commission as of December 16, 1920.

Name	Application number	Permit number	County	Source	Amount applied for—irrigation		Acreage
					Second-feet	Acre-feet	
Walker River	1,394		Mono	Virginia Creek		25,000	
Walker River	1,395		Mono	Buckeye Creek		25,000	
Walker River	1,396		Mono	Robinson Creek		20,000	
West San Joaquin	1,638		Madera-Fresno	San Joaquin River	2,500	400,000	208,000
West Side	301	270	San Joaquin	Old River	225		11,377
West Stanislaus	1,500		Fresno, Merced, Stanislaus	San Joaquin River	500		35,681
West Stanislaus	1,987		San Joaquin	San Joaquin River, Old River, Salmon Slough, Paradise Cut	500		30,000
Williams	1,554	796	Colusa	Colusa Basin, Sacramento R.	187.5		6,661
Williams	1,624	797	Colusa	Colusa Basin, Sacramento R.	65		2,593
Williams	1,655	798	Colusa	Colusa Basin, Sacramento R.	11		440
Yolo (proposed)	1,797		Lake	North Fork Cache Creek		500,000	50,000

CHAPTER XI.

RICE CULTURE.

The results of the five years' investigational work of the use of water in rice culture has been published as Bulletin No. 325 of the College of Agriculture, Agricultural Experiment Station, University of California, entitled "Rice Irrigation Measurements and Experiments in Sacramento Valley, 1914–19," by Frank Adams, in cooperation with the State Water Commission. The timeliness of this work is evidenced by the following table, showing the remarkable growth of the rice industry in California during the past six years:

TABLE 11.

Growth in Rice Industry in California.

Year	Acreage of rice harvested		
	Sacramento Valley	San Joaquin Valley	Total for State
1910	100	----------	100
1911	150	----------	150
1912	1,400	----------	1,400
1913	6,100	----------	6,100
1914	15,000	----------	15,000
1915	34,000	----------	34,000
1916	58,000	----------	58,000
1917	80,400	2,600	83,000
1918	102,000	4,220	106,220
1919	135,500	6,500	142,000
1920	154,700	8,000	164,700

NOTE.—Data for years 1910–1919 from U. S. Bureau of Crop Estimates, U. S. Department of Agriculture, and represents acreage harvested. Data for 1920 is from same source and represents acreage planted.

Rice requires much more water than general crops, such as alfalfa, corn, orchard, etc., and as the rice industry was new and no data existed as to the amount of water actually needed, the Water Commission in issuing early permits for appropriation of water for rice culture, adopted tentatively, the rate of 1 second foot to 40 acres, subject to reduction if investigation so warranted. This bulletin throws much light on the actual needs of the crop and the conditions surrounding the use of water upon it.

One of the most important factors affecting the amount of water required is the character of the surface and subsoil. The following table taken from the bulletin is very illuminating on this subject, showing that rice grown on clay soils requires the least water, and that that on clay loams and loam soils require the most:

PLATE XII.
Rice irrigation in Sacramento Valley at first flooding.

PLATE XIII
Rice irrigation in Sacramento Valley just before final flooding.

TABLE 12.

Summary of Measurements of Duty of Water in Rice Irrigation in Sacramento Valley, Seasons of 1916, 1917 and 1918, Grouped by Soil Types and Arranged in Order of Depth of Water Applied.

Soil classification	Number of full season observations	Total area included in observations. Acres	Average net depth of water applied. Feet	Average area served during full season per cubic foot per second. Acres
Capay clay	2	355	3.94	81
Willows clay adobe	7	8,477	4.22	72
Willows clay	7	5,057	5.08	70
Stockton clay adobe	12	2,877	5.13	60
Sacramento clay	4	4,653	5.72	59
Tehama clay loam and clay	2	267	8.12	43
Vina clay loam	1	302	8.13	37
Willows loam and clay or clay adobe	2	71		37
Madera clay loam, etc	1	172		37
Willows loam	2	122	9.38	36
San Joaquin loam	3	51	10.94	30
Total or average	43	22,404	4.89	66

The following extracts from the Bulletin are also to the point:

"An annual depth of five feet of irrigation water for rice is sufficient for the principal rice soils of Sacramento Valley, viz., for the clays and clay adobes of the Willows, Stockton, Sacramento, Capay and Yolo series. Pervious loam soils require an excessive amount of irrigation water, and from a water standpoint are not suitable for rice growing.

The use on individual fields of 1 cubic foot per second of irrigation water to 30 or 40 acres during the first flooding after seeding is not excessive. Owing to the fact that all growers are not ready for the first flooding at the same time, canal diversions at this rate are not necessary, although probably as much as 1 cubic foot per second to about each 50 acres served is desirable during the period of initial flooding. The seasonal use averages about 65 acres per cubic foot per second.

About one-third of the water applied to rice fields is lost by evaporation from the surface of the standing water during submergence. This factor in the duty of water cannot be controlled." (Pages 67 and 68.)

* * * * * * *

"It is imperative that ground water and rise of alkali be controlled in California rice fields both by confining rice growing to the heavier, impervious clays and clay adobes, and by thorough and adequate drainage facilities embracing the entire areas affected." (Page 68.)

* * * * * * *

"The well-known injury that results to lands from rise of ground water, with attendant damage from alkali, will in time automatically reduce the area that can profitably be devoted to rice growing unless both preventive and corrective measures of radical nature are taken. This injury may be both to the lands planted to rice and to neighboring lands in which the ground water is brought up through the large amount of water applied in rice growing. *The most important preventive measure is to restrict rice growing to soils that do not require over, say, 5 acre-feet of water per acre per annum such as the clay and clay adobes of the Willows, Capay, Yolo, Stockton and Sacramento series* (italics ours) already referred to as being, so far as observations have gone, the most satisfactory soils, from a water standpoint, for rice growing. *It cannot be too emphatically stated that the continued growing of rice on loam soils not underlain by an impervious stratum that prevents deep percolation of water will result in very great damage.* Fortunately, the higher cost of irrigating loam soils devoted to rice will, as the price of rice again becomes normal, tend to eliminate such soils from this crop." (Page 65.)

* * * * * * *

"No study of rice irrigation can overlook the great damage done to rice fields by water grass. At present, outside of irrigation and drainage, this pest is the controlling factor in the permanence of the rice industry in California. It seldom does great

damage in the first year on new or adequately fallowed land, but with a normal price for rice *three years is practically the limit of profitable rice growing* until the fields are again cleared." (Page 66.) (Italics ours.)

Opinion among rice growers seems to indicate that when the rice industry stabilizes, the acreage under any project capable of growing rice will in any one year seldom be more than 50 per cent actually planted to rice, the balance either lying fallow to eradicate water grass, or being planted to general crops requiring much less water. Under such conditions, the results obtained from the investigation by the Department, quoted from above, would indicate that a headgate duty of 1 second-foot to 80 acres would be sufficient for rice culture with favorable soil conditions. This view is held by private engineers who have given the subject careful study in the Sacramento Valley. The attainment of such a duty would go far toward greater and more efficient use of the waters of the Sacramento River than at present.

CHAPTER XII.

USE OF WATER FROM KINGS RIVER.

The report of the studies carried on by the United States Department of Agriculture and State Department of Engineering in cooperation with the State Water Commission on Kings River have been published as Bulletin No. 7, State Department of Engineering, entitled "Use of Water from Kings River, California, 1918," by Harry Barnes.

The following paragraphs from the letter of transmittal of this report by Mr. Frank Adams, Irrigation Manager, summarizes the extent of the problem, and the most important conclusions:

"Kings River, with an average annual discharge of approximately 2,000,000 acre-feet, is the largest stream entering San Joaquin Valley, and at this writing is irrigating a larger area than any other single stream in California. The extent, variety and value of the products grown by means of the water furnished by this river give to it a rank second to none among irrigation streams in the state. Just now it is one of a half dozen or more major California streams for which plans for storage are being worked out on a scale not heretofore seriously attempted in this state; and with the possible exception of Kern River, organization for flood water conservation presents more complications on Kings River, on account of the extent and diversity of interests involved, than on any other California stream. The importance at this time of a thorough public understanding of irrigation methods and practices on this river, of the economy or lack of economy with which irrigation water from it is applied, of what is needed to make conditions better, and of the inter-relations of irrigators and irrigation companies and of irrigation companies among each other is obvious.

What might be termed the Kings River area comprises in round numbers about 2,000,000 acres. Some 29 principal canals are now carrying water from the Kings to a maximum of about 550,000 acres, with some variation, depending upon whether the annual flow is below or above normal. Preliminary engineering studies indicate that within present standards of economical construction and storage it is feasible to increase the irrigated area to from 850,000 to 1,000,000 acres, with an estimated expenditure of $12,000,000. This can only be brought about, however, through close and unselfish cooperation between the numerous individual, corporation and community interests concerned, involving a type of irrigation organization not yet tried, and therefore not yet perfected in this country. It is not even unreasonable to assume, also, that the accomplishment of the purposes of the present water conservation movement on Kings River may involve a degree of participation, both financial and regulatory, by the state or the federal governments, or both, that will be new." (Pages 3 and 4.)

* * * * * * *

"The two features of the situation on Kings River that stand out most prominently are the need for public supervision of diversions on the basis of a clearly defined list of priorities, and a more systematic and hence a more economical administration of the distribution of water to irrigators. Mr. Barnes' very clear analysis of past litigation on Kings River and of present uncertainties as to rights due to the complicated nature of the litigation and its subsequent modification under both written and oral agreement, shows how much the situation might be improved if a single water master representing the state were in charge of all diversions. The very full statements regarding the character of present use convincingly emphasize the public gain that would follow a better management of the individual irrigation companies. The reasons for present uneconomical management of canal systems, to some extent justified by the lack of storage, are fully given, and when once these reasons are understood, the desirability of such storage as is proposed will be clearer." (Pages 4 and 5.)

In the light of the above, the water users on Kings River are to be congratulated for the public spirit and initiative which prompted them during the season of 1919 and 1920, to voluntarily agree to a partial schedule for division of the waters of Kings River in accordance with prior rights and the distribution thereof by an engineer of the Commission, as described elsewhere in this report. It is to be hoped that all local differences can be overcome and a schedule worked out for the full range of flow of the stream for which rights have been acquired. Studies such as that carried on by the Department of Agriculture are of great value in pointing out clearly the causes and remedies for unsatisfactory conditions attendant upon the distribution and use of water.

APPENDICES.

APPENDIX A.

FINANCIAL STATEMENTS.

CALIFORNIA STATE WATER COMMISSION.

Statement of Income and Expenditures for the Sixty-Ninth and Seventieth Fiscal Years—As at June 30, 1919.

	Sixty-ninth fiscal year 1917-1918	Seventieth fiscal year 1918-1919	Total
Income from appropriations:			
Salaries of Commissioners—Chapter 358—1917	$15,000 00	$15,000 00	$30,000 00
Support—Chapter 358—1917	37,784 14	47,277 79	85,011 93
Total income from appropriations	$52,784 14	$62,277 79	$115,011 93
Expenditures:			
Administration	$27,998 68	$29,270 75	$57,269 43
Applications for water	14,102 99	18,197 96	32,300 95
Adjudications	3,474 91	5,655 53	9,130 44
Stream gauging	7,157 56	8,613 55	15,771 11
Special surveys		540 00	540 00
Total expenditures	$52,734 14	$62,277 79	$115,011 93

CALIFORNIA STATE WATER COMMISSION.

Statement of Income and Expenditures for the Seventy-First and Seventy-Second Fiscal Years—As at September 1, 1920.

	Seventy-first fiscal year 1919-1920	Seventy-second fiscal year to Sept. 1, 1920	Total
Income from appropriations:			
Salaries of Commissioners—Chapter 645—1919	$10,202 02	$1,763 30	$11,965 32
Support—Chapter 645—1919	38,179 82	10,570 49	48,750 31
Appropriation for Santa Ana River study	4,999 93		4,999 93
	$53,381 77	$12,333 79	$65,715 56
Expenditures:			
Administration	$24,313 47	$4,960 38	$29,273 85
Applications for water	15,250 22	4,602 77	19,852 99
Adjudications	4,418 96	1,583 63	6,002 59
Federal departments:			
Stream gauging U. S. Geological Survey	4,399 19	757 01	5,156 20
Special survey—U. S. Department of Agriculture		430 00	430 00
Santa Ana River study	4,999 93		4,999 93
	$53,381 77	$12,333 79	$65,715 56

APPENDIX B.

WORK OF LEGAL DEPARTMENT.

By L. D. BOHNETT, Attorney.

During the last two years, the legal work of the Commission has increased rapidly. For some time after the appointment of an attorney by the Commission in the fall of 1915, his duties consisted largely of answering questions relative to applications for appropriation of water. With the great growth in the number of applications and the increasing scarcity of water, the questions of law which must be determined in acting upon the applications have increased both in number and complexity. In addition, a number of cases have been referred to the Commission by the courts, ascertainment of the rights on certain stream systems has been undertaken, and in other ways the work of the Commission has been broadened and the work of the legal department thereby increased.

Among the cases referred to the Commission was that of *Bee Creek Ditch Company et al.* vs. *Happy Valley Irrigation District et al.* Originally only part of the appropriators on the stream, the North Fork of Cottonwood Creek, were made parties to the action. At the suggestion of the Commission, all users of water along this stream and its tributaries were made parties, so that there might be a complete adjudication of water rights on the stream in the one action. After the engineering department of the Commission had made a careful investigation of the facts relative to this case, including the taking of stream measurements and the measurements of all ditches carrying water from the stream, the case was set for hearing at Redding. Before taking testimony, the Commission suggested to the attorneys (more than a dozen in number) of the respective parties, that they sit down with the Commissioner present and the Engineer and Attorney of the Commission and endeavor to agree upon a decree. The suggestion was favorably received, and after three days of conference a stipulation was signed by all parties pursuant to which a decree was entered, finally determining all rights to the use of water from the stream system involved. Had the case proceeded to hearing, it would have taken at least three weeks to hear the testimony, and it is hardly conceivable that the matter could have terminated with as great satisfaction to the parties.

The Cottonwood Creek case is typical. Other cases referred to the Commission are being handled in the same way. The Commission as a disinterested body with means of ascertaining the essential facts of the

case without a tedious hearing is able to bring litigants together where a court with its more formal procedure would fail. By this means—the reference of cases by the courts to the Commission—it is hoped that the rights on many stream systems may be adjusted with comparatively small expense.

Ascertainments of water rights by means of the procedure set forth in sections 25 to 36*f* of the Water Commission Act, as well as cases referred to the Commission by the courts, have added to the work of the Commission's legal department. Each ascertainment involves not only questions of procedure but gives rise to many questions of law relative to water rights which are referred to the attorney. Many novel questions have thus arisen, which can be decided only after careful study.

One of the most important duties of the Attorney for the Commission during the past year has been the defense of two petitions filed by the Tulare Water Company in the superior court of the city and county of San Francisco for a writ of mandate and a writ of review, respectively. The application of Tulare Water Company for permit to appropriate water from Buena Vista Slough in Kern County, was rejected by the Executive Member of the Commission for the reason that there was insufficient water to make the proposed use feasible. Upon appeal the Commission affirmed the order of the Executive Member. Tulare Water Company thereupon filed its petition for a writ of mandate to compel the Commission to issue the permit asked for. The demurrer of the Commission to the petition was sustained without leave to amend. Tulare Water Company then filed its petition for a writ of review in the same manner. The Commission's demurrer to this petition was also sustained without leave to amend. Appeal was taken from each of the orders and the appeals are now pending in the District Court of Appeal.

The Commission believes that its usefulness will be greatly decreased, indeed practically ended, should the writ of mandate issue. In opposing the petition the Commission contends that the Water Commission Act clearly vests the Commission with a certain amount of discretion and that the Commission acts quasijudicially in determining whether an application should be allowed or rejected. Should the courts hold otherwise the Commission would be compelled to approve every application filed if the application be in proper form. The Commission contends that the legislature never intended so to circumscribe its powers. As the matter is still pending in court, however, it would hardly be proper to discuss it in this report other than to very briefly summarize the argument of the Commission as presented in its briefs filed with the court.

Questions submitted to the Commission's Attorney are not by any means limited to the work of the Commission. People from all parts of the state write to the Commission for information relative to the law applicable to their water rights or claims. Very many of these questions are clearly without the jurisdiction of the Commission, but they are nevertheless answered whenever the Commission believes that it can be of service.

A recent decision of the District Court of Appeal relative to the legal effect of an application to appropriate water should perhaps be noted in this report, though the Cmmission was not a party to the suit in which the decision was rendered. In *Barr* vs. *Branstetter et al.,* 29 Cal. App. Dec. 597, it was contended that the application to the Water Commission for a permit to appropriate was an admission that the party had no water right. The court held, however: "Nor was the application an admission that he had no right to any of the water. It was simply an attempt legally to secure, if he could, more water than he at that time had." The Commission is frequently asked whether an application is a waiver of existing rights. The decision quoted herein seems to be a complete answer to the question.

Another branch of the work of the legal department consists of the drafting of proposed legislation and presenting the bills before the legislature. In 1917, and again in 1919, important amendments to the Water Commission Act and allied laws were made at the suggestion of the Commission. Again in 1921, bills will be offered for the purpose of strengthening weak points in the act under which the Commission operates, and of making the Commission more useful to the water users throughout the state. In cooperation with other departments a check is also maintained on all bills affecting the use and application of water.

No attempt is made in this report to set forth in detail the work of the Commission's legal department, as such report would be tedious and of little value. The report is, therefore, merely an outline of some of the more important lines of work which fall to the Commission's Attorney. As stated above, the work of this department has increased rapidly within the last two years, and it bids fair to increase more rapidly during the next two years. The demand for water is growing day by day and as the supply is limited the contention for what there is grows ever keener. Present users of water are, therefore, seeking to throw every safeguard around their rights and new appropriators are seeking by every lawful means to acquire new rights. This activity will undoubtedly keep the legal department as well as all other departments of the Commission increasingly busy.

APPENDIX C.

INVESTIGATIONS ON KERN RIVER.

Following various conferences between the different interests in Kern County and the state agencies concerned with irrigation, in the latter part of 1919, funds were provided for an investigation of the resources for irrigation and their utilization in the portion of the county tributary to Kern River. The field work has been under the direct supervision of the State Department of Engineering with the active cooperation of the State Water Commission. The sum of $5,000 each was contributed by Kern County, the Kern County Land Company, the Tejon Ranch Company, and the State Department of Engineering. In addition, Kern County has furnished office facilities and the use of county cars, the canal companies have made available all data which they had bearing on the investigation, and the State Department of Engineering has furnished equipment and also funds in addition to its original allotment of $5,000. The State Water Commission has assisted by assigning an engineer from its field force to this work during its organization and by making available all of its data concerning this area. The members of the Commission have also assisted in the outlining of the work to be done, and have kept closely in touch with its progress.

Prior to the undertaking of the field work filings were made with the Commission covering the storage and power which might be developed by any comprehensive undertaking on this stream. These filings were made by certain residents of the area, for the benefit of any irrigation district that might result from the work, acting as trustees for such proposed district. Necessarily, the data was not available for a complete application, and extensions of time for completion have been granted during the progress of the work.

Any essential or material improvement in the present conditions of irrigation from Kern River will require the regulating of the flow of the stream by storage. It will also require the full utilization of the available ground water supplies by pumping. As quite complete records of the runoff of the river and its present character of use by the canals of the Kern County Land Company were already available, the attention of the field work has been largely directed toward a study of the present use of water by pumping, its limitations of supply and the areas where it could be continued to the greatest advantage. Much attention has also been directed to the study of storage, the capacity required, the feasibility of the one large site available, and the

probable cost. As there are now three power plants in operation in the portion of the river between the proposed reservoir site at Isabella and the mouth of the canyon, considerable study has been given to the effect of such river regulation on the present supplies of such power plants and the feasibility of additional development of power from the regulated flow. The data available regarding the use of water on the lower portion of Kern River being meager, surveys of the reservoir used and observations of the character of the use of water there have been made in the field. In addition, all available data in any way relating to the use of water from Kern River has been collected and analyzed.

The field work has been carried on with an average of three field engineers working singly or as the head of parties. The understanding under which the work was undertaken included an estimate that one year's time would be required for the completion of the field work and the preparation of the report. This time will expire in January, 1921, and it is expected that the conclusions and recommendations can be completed by that time. The actual assembling and publication of the complete report will require some additional time.

It is planned to make a report covering the extent and character of development of the waters of Kern River, which it is considered will secure the most practical and complete use of this resource. This requires a consideration of what would be most desirable if the development were to be undertaken with no present uses to conflict with or to require adjustment to fit into such a general scheme, and also the extent to which any such idealized plan must be modified to meet existing conditions. The work so far done indicates that a much better utilization of the water resources can be made than are at present obtained, but it has not proceeded far enough to formulate the recommendations, as to definite steps to be taken for such utilization, to be submitted. The physical features of the problem are more favorable than those existing on many other streams where greater progress has been made. The matters of organization and methods of putting the desired development into effect are more complicated in this stream than in some others.

The work has at all times had the hearty assistance of all parties cooperating in it. This has made possible the accomplishment of a greater amount of work with the given funds and in the allotted time than could have been obtained otherwise. It is hoped that the result will justify the time and funds expended and be of assistance in bringing into harmony the various interests on this stream.

APPENDIX D.

SALINITY INVESTIGATIONS IN THE SACRAMENTO AND SAN JOAQUIN RIVER DELTA.

The salinity problem in the Sacramento and San Joaquin River Delta region has ceased to be a problem of the future; on the contrary, it has become a problem of the present, and one that should be solved at the earliest possible moment.

For several years the advance of water from San Francisco Bay has been roughly noted by various parties, but the problem had not become serious enough to result in the collection of reliable data that would be of use in finding a remedy for the condition. One of the first results of the advance of the salt water was the appearance of the marine borer, or torredo, in the piles supporting wharves and ferry slips in the vicinity of Crockett and Port Costa. Piles that had been supporting these structures for many years, and which were in first-class condition, were suddenly attacked and ruined by these salt water borers; next, the towns further up the river that had been using the river water for municipal purposes were compelled to discontinue such use and seek supplies elsewhere, usually from wells. The town of Antioch, which has used river water ever since its first settlement, has been unable to get water fit for domestic use since July of the present year. This condition has not previously existed to this extent.

The probability that the salinity problem would become a serious one has been recognized by the Water Commission for several years. The first activity on the part of the Commission to make a study of the situation was in October, 1916, when a very preliminary investigation was made in the delta. Again in September, 1919, another series of tests were made and a much higher concentration of salt was found. No doubt a part of the increase was due to the decrease in flow as a result of dry year conditions, but it is maintained by many reliable parties that the great increase in up-river diversions for irrigation purposes is also responsible. Other minor causes probably exist.

In the early spring of the present year, 1920, it was evident that flow conditions in the lower Sacramento and San Joaquin Rivers would probably reach a lower stage than had ever been known, and as a result, salt water from the Bay would probably find its way to points heretofore immune.

A preliminary survey was made late in February and evidence was secured which indicated that it would be an ideal season for making a thorough study of the problem. Water Commission funds were

extremely limited for such a use, and the question was taken up wi private interests in the Delta region and also with the State Enginee ing Department. As a result, funds were made available by the Riv Lands Association, an organization of delta land owners, and the Sta Engineering Department, and the State Water Commission agreed cooperate in furnishing the personnel and equipment. It was plann to carry on as intensive an investigation as was deemed expedient und the circumstances.

The gathering of data was regularly begun May 25, 1920, und the writer's supervision, and the first stations were established for t collection of samples by local observers. From time to time, additio stations were added until a total of twenty-eight stations were sendi in samples regularly by mail. (Diagram 4.)

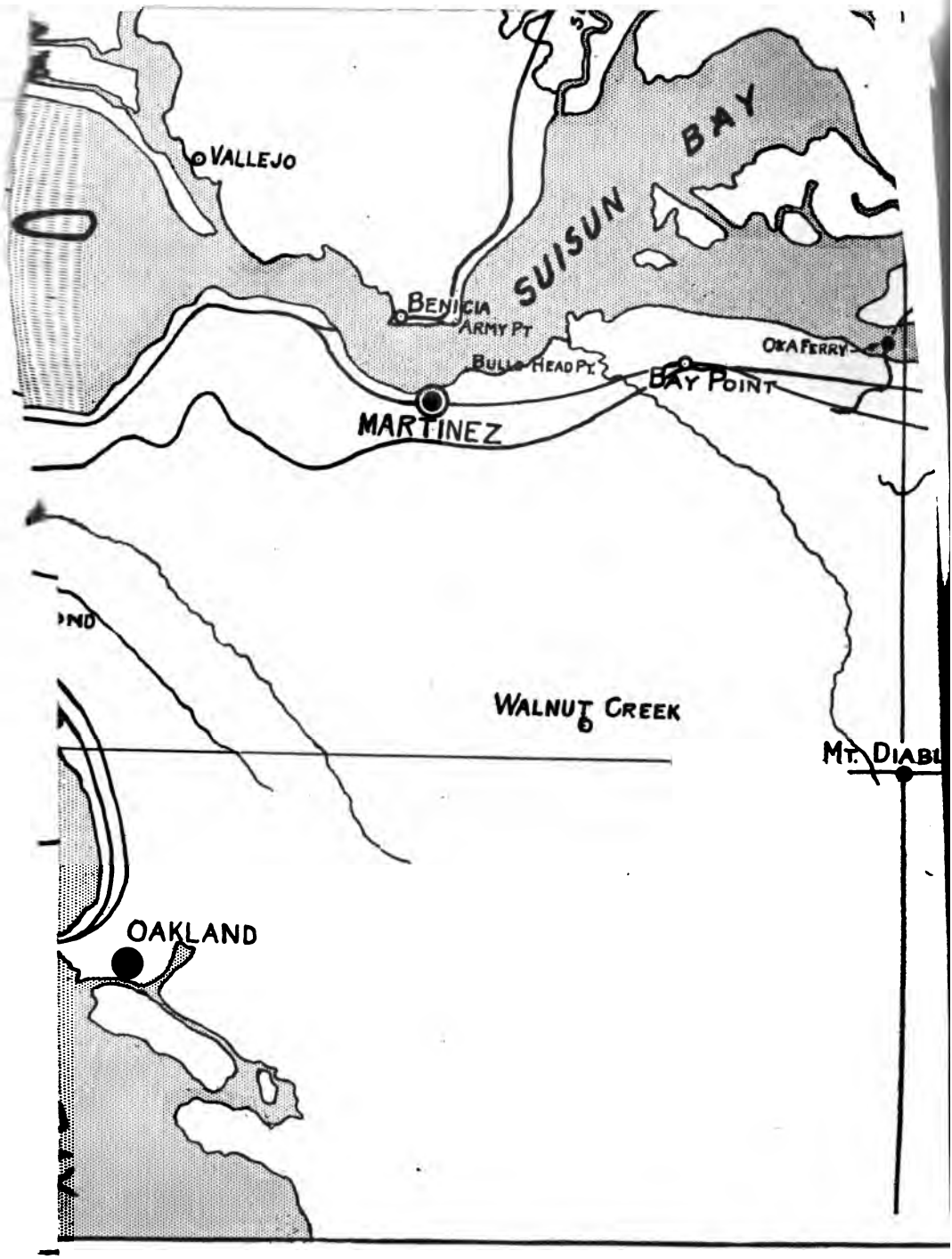
At intervals of from one to three weeks, trips were made over t area under consideration by launch, for the purpose of making a special investigation that appeared pertinent, and also for the purpo of visiting the various stations to direct any changes in procedure th might be necessary.

All samples collected in connection with this investigation ha been tested for chlorine by titration with silver nitrate, the par of chlorine being expressed in parts per hundred thousand. If it considered that all of the chlorine is in the form of sodium chlori (salt), the results should be multiplied by 1.65 in order to get par of salt per 100,000.

The local observers gave their services gratis and the Commission greatly appreciates the willingness and zeal with which they cooperated.

Great activity in the gathering of data bearing on the causes, extent and results of the encroachment of the salt developed as a result of the filing by the city of Antioch on July 2, 1920, of petition for injunction against upriver users of water from Sacramento River. Extremely valuable data has been collected for use in this controversy, and it is to be hoped that constructive and equitable use will be made of it.

An examination of the accompanying diagram (Diagram 5) will reveal the fact that salt from the bay made its appearance at the mouth of the Sacramento and San Joaquin Rivers (at Collinsville) about July 1, and reached its maximum intensity about September 15, when it began to diminish, due to the increased flow in the Sacramento River. The latter had apparently reached a stage at that time sufficently large to commence the flushing out of the channel. The increase in the river discharge occurred at about the time up-river diversions for irrigation ceased. Further increases occurred during the general rainstorm which passed over the State in the early part of


VALLEJO
SUISUN
BAY
BENICIA
ARMY PT
BULL HEAD PT
O&A FERRY
BAY POINT
MARTINEZ
WALNUT CREEK
MT. DIABL
OAKLAND

STATE WATER COMMISSION

SKETCH MAP OF

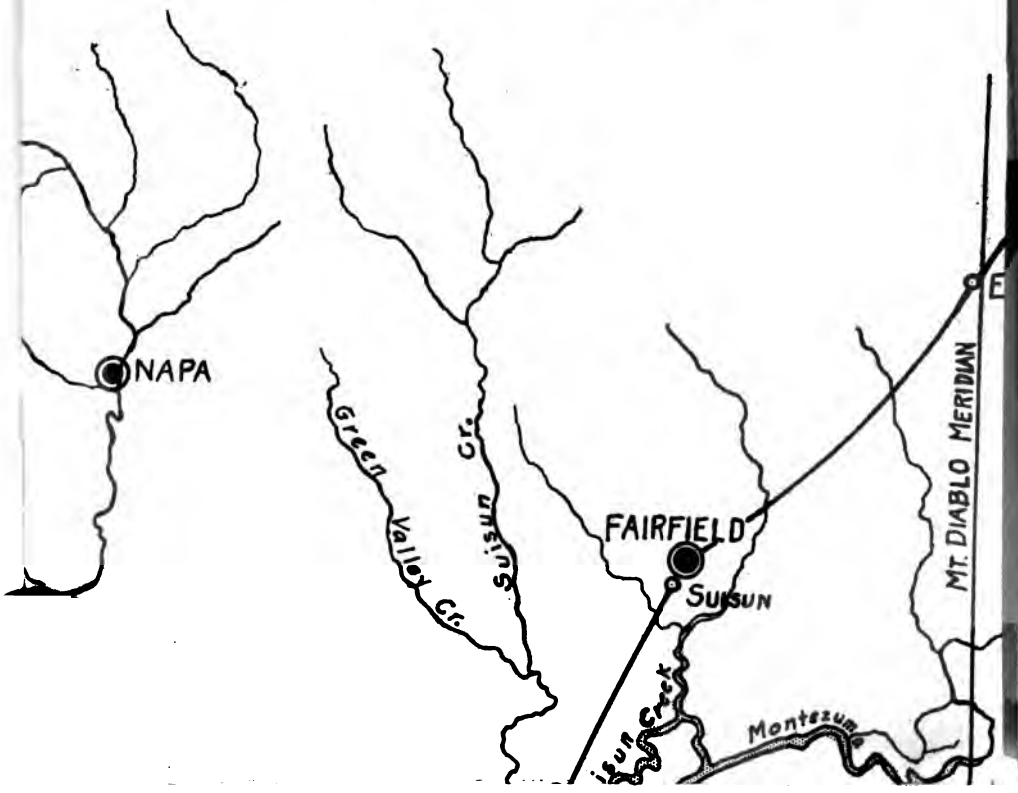
SACRAMENTO - SAN JOAQUIN DEL

WITH REFERENCE TO

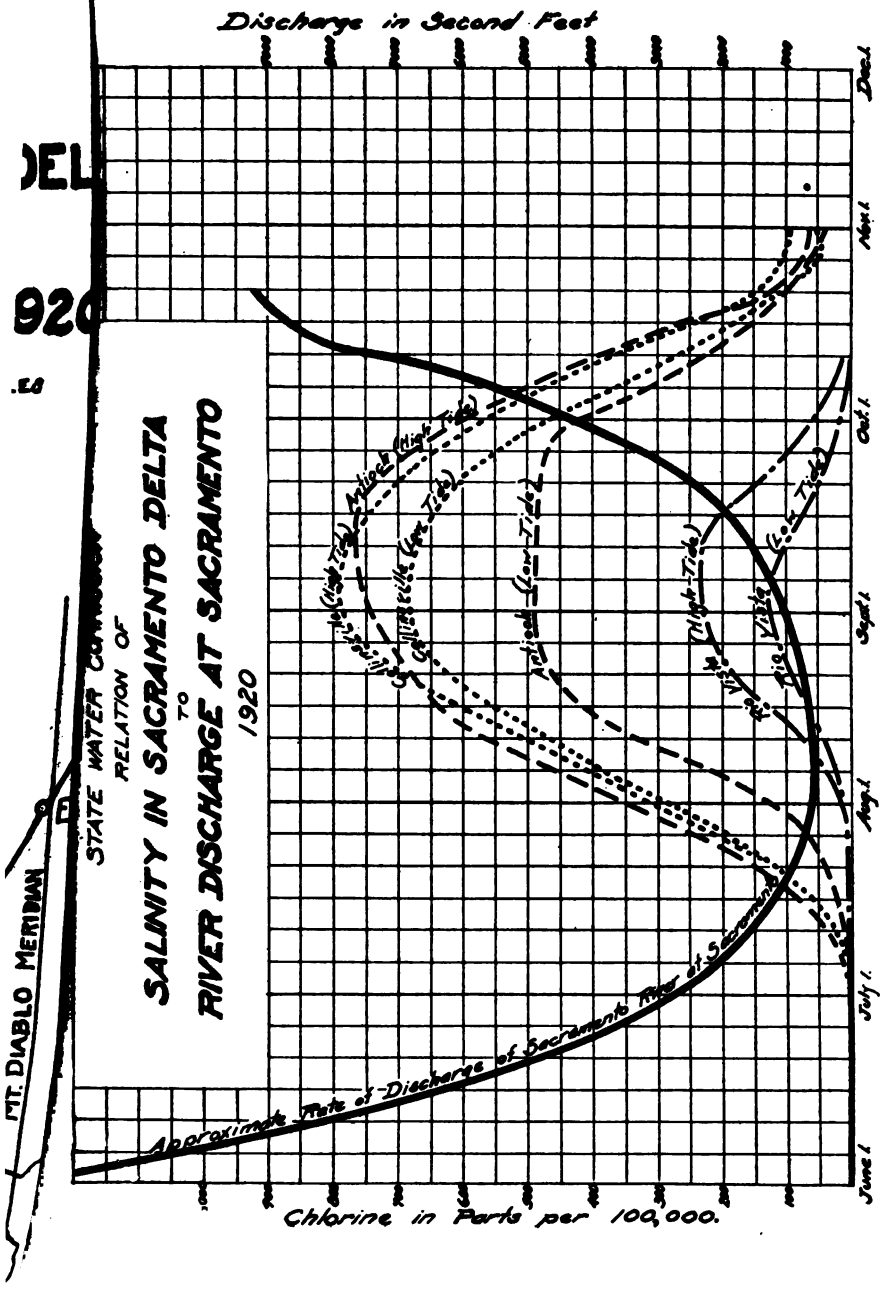
SALINITY INVESTIGATIONS 192

● INDICATES POINTS FROM WHICH WATER SAMPLES WERE REGULARLY RECEIVED

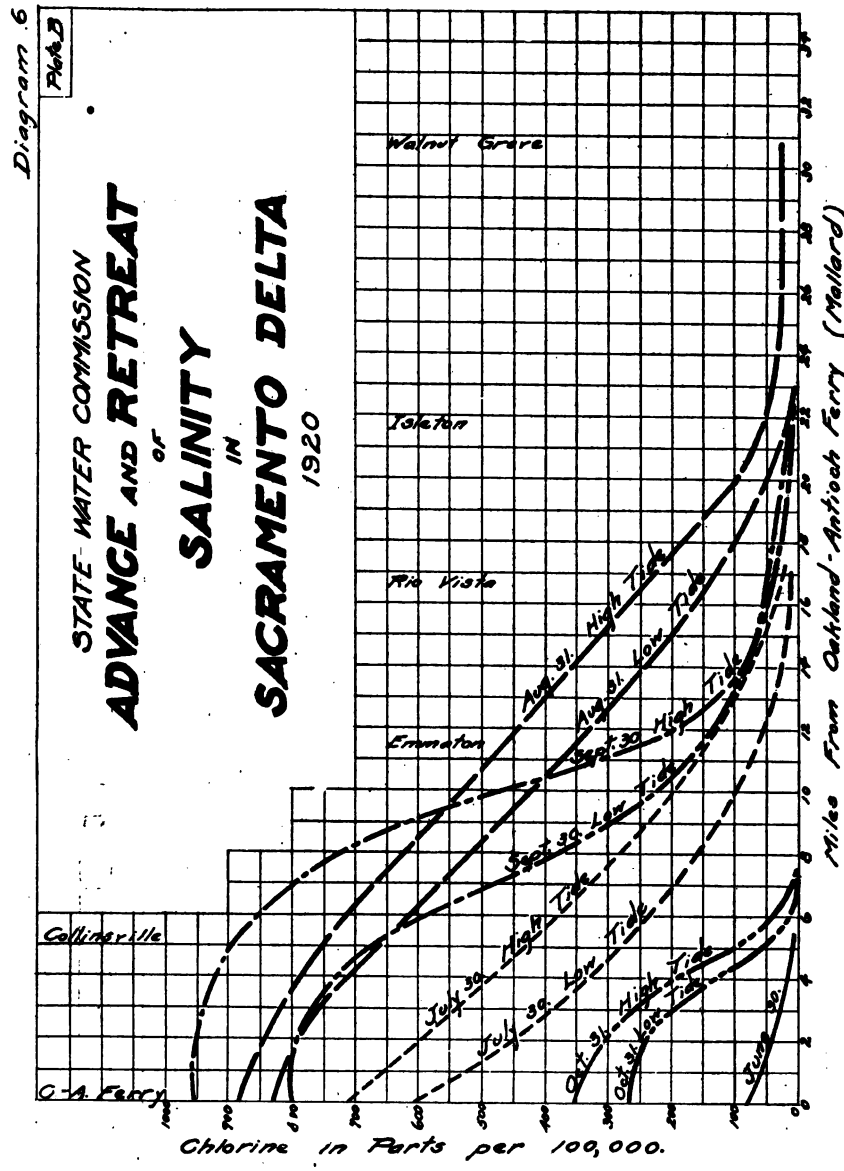
SCALE 0 1 2 3 4 5 6 MILES



ober. By the end of October, the Sacramento River and the ams directly controlled by it had become free from salt, with the ption of the channel at Collinsville and immediate vicinity. gram 6 shows graphically the manner in which the salt was pushed



The analysis of conditions in the lower San Joaquin Delta is much more complicated than for the Sacramento. Conditions are affected greatly by the flow in the Sacramento via Three Mile Slough, Seven Mile Slough and Georgiana Slough. The degree of influence exerted by these different feeders depends on the varying stages of the two main rivers, and for this reason exceedingly complete data taken over an extended period would be necessary in order to give definitely the



conditions at any particular time. Information at hand is not considered as sufficient for this purpose, and hence Diagrams 7 and 8 indicate only in a general way the varying conditions. River flow curves of both the Sacramento and San Joaquin rivers are shown on

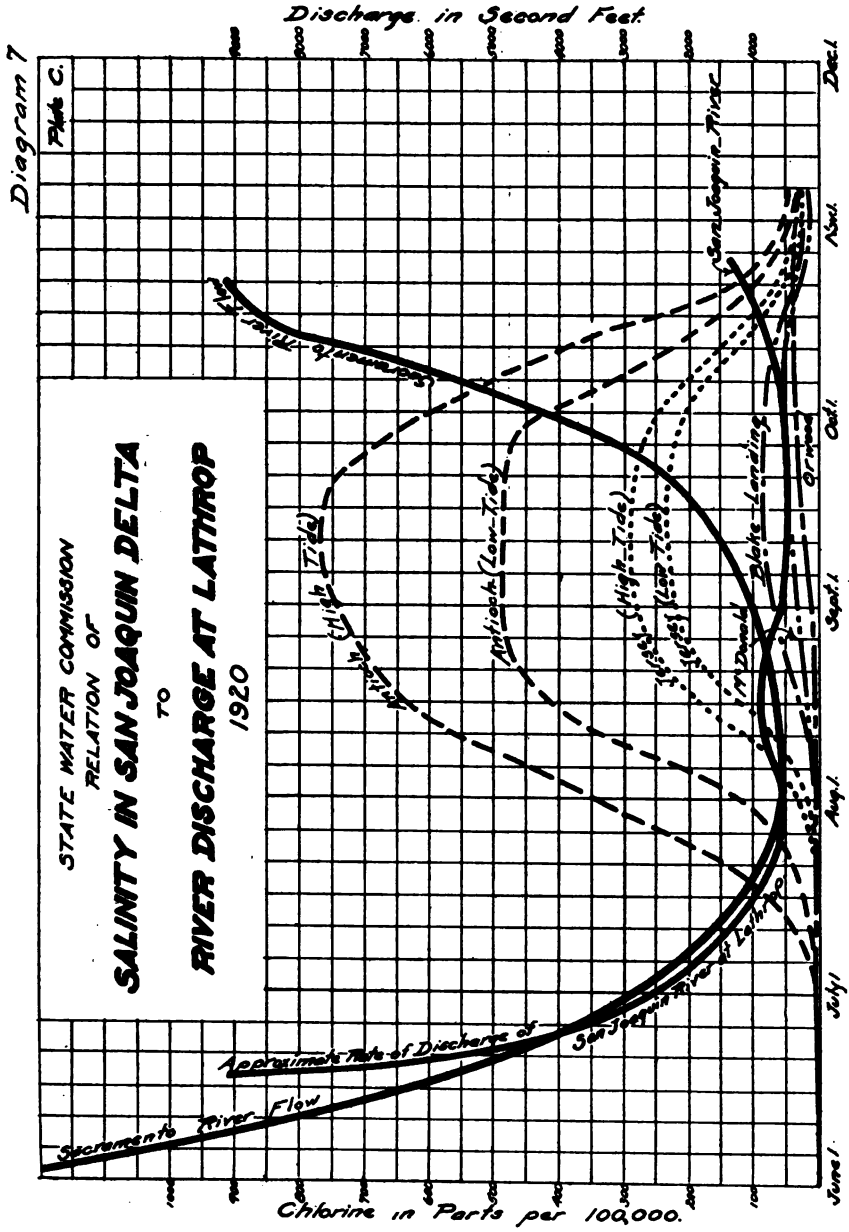
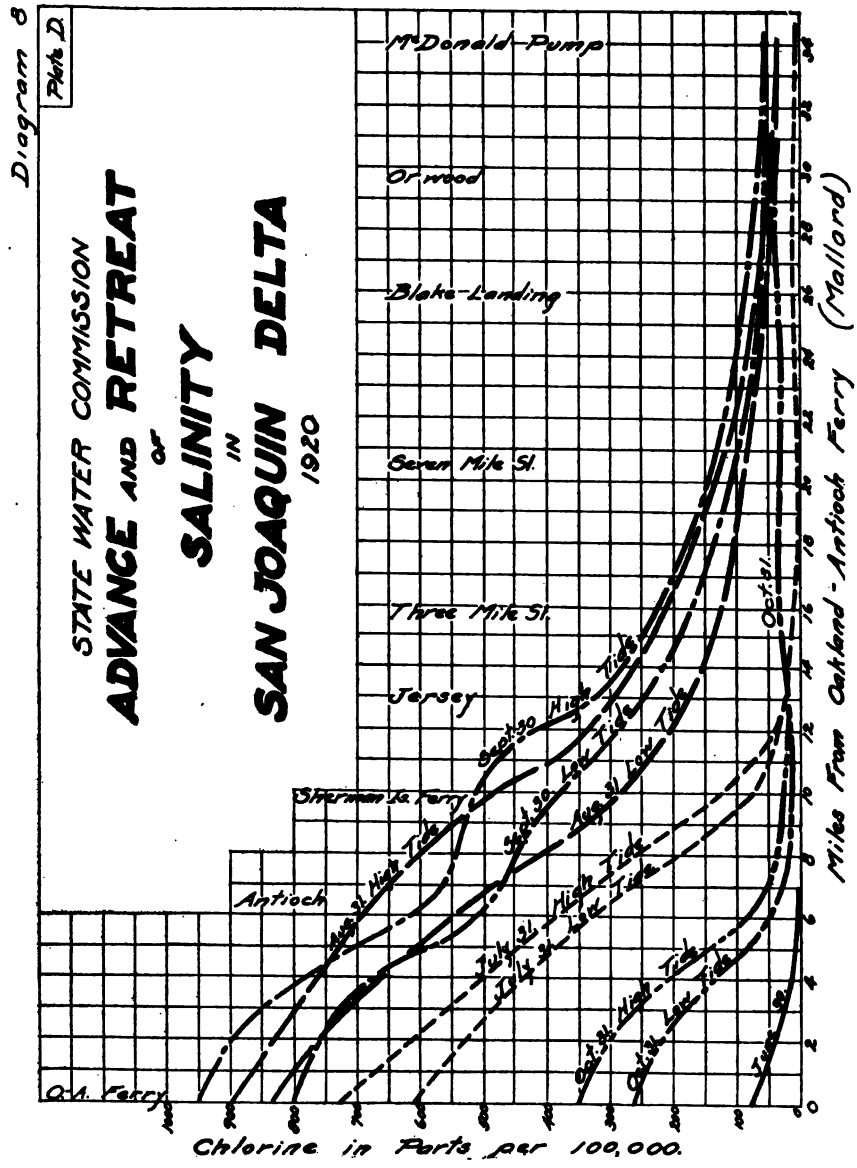
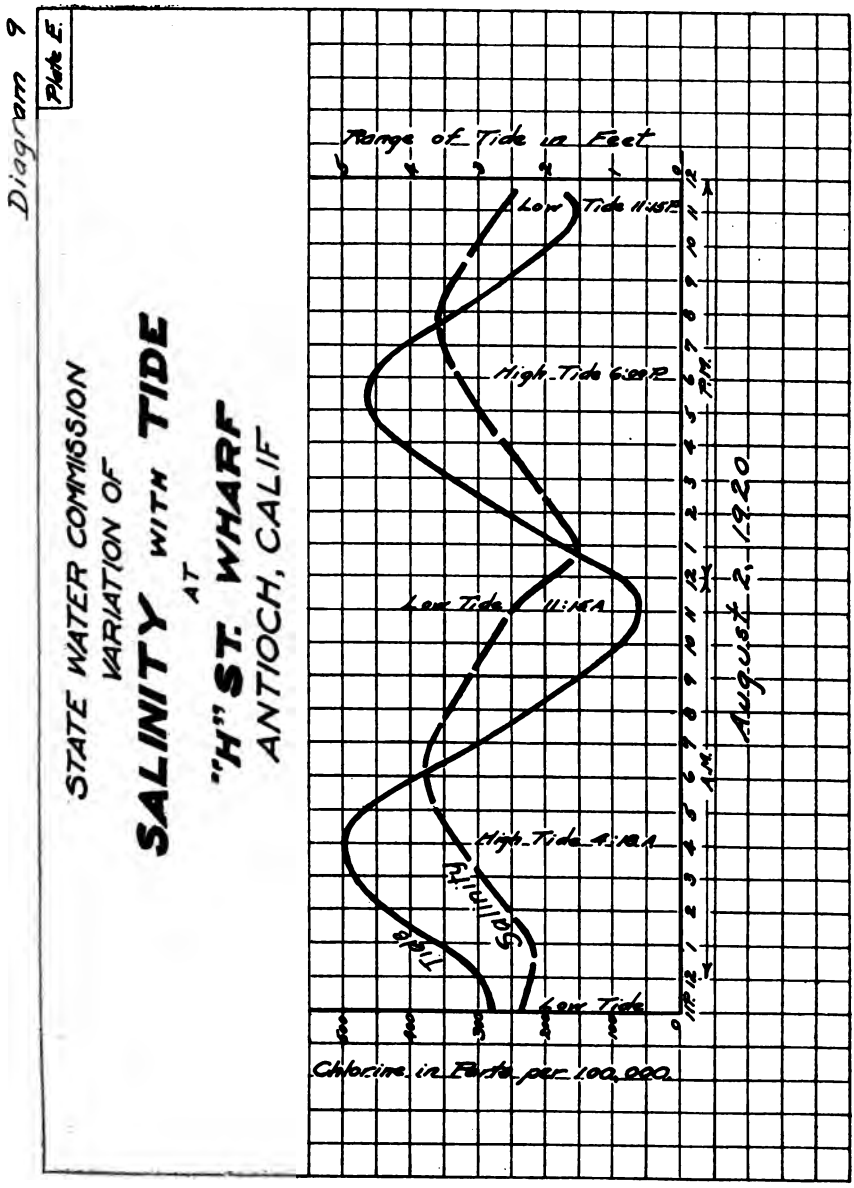


Diagram 7, since changes of salinity conditions in the lower San Joaquin Delta during this season were caused almost entirely by the relatively large increase in flow in the Sacramento. This is shown by the way the Antioch and Jersey salinity curves begin to drop when the flow of the Sacramento reached 2500 to 3000 second feet. It should also be noted that the up-river stations, such as McDonald Pump and Orwood, which are not affected by the Sacramento River, have shown



a comparatively small decrease in salinity. This is particularly true of Orwood, which apparently felt but very slightly the effect of the October rain storm.

Diagram 8 shows the decided effect of the Sacramento River in freshening the water of the lower San Joaquin. It will be noted that the October 31 curve is considerably lower below Three Mile Slough than



above. This is undoubtedly caused by the large flow of fresh water through Three Mile Slough from the Sacramento River at low tide stages.

The relation of the chlorine content to the tide was investigated at Antioch on August 2, 1920, and it was found that the maximum and minimum salinities occurred two hours after high and low tides, respectively. (Diagram 9.) This phenomenon of lag in time appears to exist throughout the Delta, but is not constant at all points. The Army engineers at Benicia found a lag of from one and one-half to two and one-half hours at that point, and private parties have found a lag of approximately two hours at Three Mile Ferry and at Rio Vista. This condition was recognized in the drawing of samples in the lower Delta. It is also observed by all users of water in the Delta during the latter part of the season.

The variation of salinity with depth was investigated at various times and in various localities, but the results obtained do not justify a definite conclusion as to the manner in which the variation takes place. Roughly, it appears that the rate of variation increases as the intensity of salinity increases. Also, results were obtained which indicate that the salt water encroaches to some extent by advancing under the fresh water. This condition may result from the settling of salt water into holes along the channels as it comes in on the flood tide and partly remaining there during the ebb tide.

Several methods of control of the up-river movements of the bay water have been suggested. They may be classed as the "direct" and "indirect" methods. The direct method suggested is the construction of a collapsible dam and adequate locks at any of the following sites: (1) Point Richmond; (2) Army Point; (3) Chipps Island (near the Oakland-Antioch Railroad ferry.) This method would provide a definite barrier during periods of low river flow, and which would be removable, or practically so, during flood periods in the rivers. Proponents of this idea maintain that it is feasible, and cite several precedents in support of their scheme. Aside from the great cost of the project, probably the greatest opposition to this scheme will arise from the ever present sentiment against radical changes in existing conditions.

The indirect method involves some way of maintaining the flow of the rivers at their mouth at a rate of discharge such that the channel will be kept flushed out. The most favored method of accomplishing this result is by the development of storage on the main streams and their feeders, and the release of this stored water at the proper times.

In conjunction with the development of storage, it is suggested that water masters, appointed by, and responsible to, a centralized authority,

supervise the distribution and use of water from the main streams. This would result in a much more efficient use of water which, in turn, would result in maintaining a greater flow in the stream.

By the development of highly efficient drainage systems and the use of neutralizing agents on the soil, it may be possible to use water for irrigation which at present would be considered ruinous. If the winter rains that follow the use of this questionable water do not prove adequate to leach the salt from the soil, it would be possible to flood the land in the early spring with fresh water, and by means of the drainage systems quickly draw off this water in time for the planting of crops.

In short, the solution to the problem may not be found in the adoption of any one scheme, but by the combination of all the means available. The great need is the adoption at the earliest possible moment of a definite program by some recognized authority, and having once been adopted, this program should be adhered to by all interests under the guidance of a centralized head.

PLATE XIV
Upper measuring station on Alameda Creek.

PLATE XV.
Measuring Alameda Creek by wading above the upper station.

APPENDIX E.

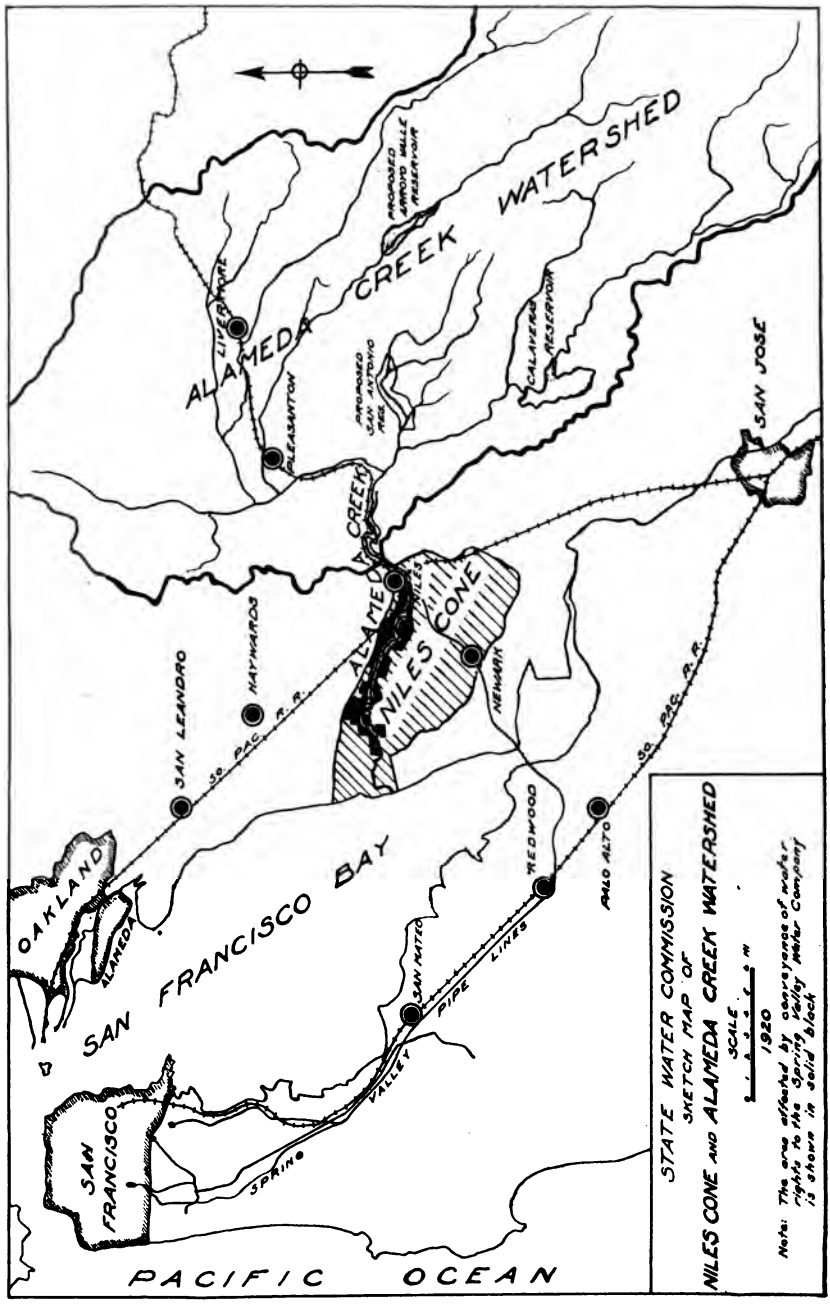
ENGINEERING INVESTIGATION OF PERCOLATION FROM ALAMEDA CREEK AND GROUND WATER STUDIES ON NILES CONE.

By PAUL BAILEY, Hydraulic Engineer.

In September, 1916, the Spring Valley Water Company and Alameda County Water District signed an agreement placing their controversy over the title to the waters of Alameda Creek before the State Water Commission for adjustment. The contentions of these parties involve the source of a considerable portion of the potential water supply for the city of San Francisco, including the projected building of several large storage reservoirs, and the waters irrigating one of the most intensively productive agricultural districts bordering San Francisco Bay. Both parties believing that a solution of their difficulties might be arrived at through an impartial survey of physical facts, agreed upon the State Water Commission as the proper body to direct an engineering investigation upon which the merits of their respective claims might be judged.

The contentions of these parties involve many very intricate problems in science. The Alameda County Water District maintains that the storage proposed by the Spring Valley Water Company for increasing the water supply for San Francisco will interfere with the normal replenishment of the underground waters upon which their irrigation wells draw. The merits of this claim depends primarily upon the relation that may exist between the flow in Alameda Creek and the replenishment of the underground waters of the territory adjacent to the lower reaches of the creek. The impossibility of placing values upon intangible quantities of this nature other than by thorough scientific inquiry is at once apparent. The procedure adopted by these parties is therefore the only logical program for dealing with such complicated problems in hydrology as this controversy is founded upon.

The Spring Valley Water Company is proposing to develop about 100 million gallons per day additional supply for the city of San Francisco by the construction of reservoirs and other works on the upper watershed of the creek. Their program is threatened by the claims of the Alameda County Water District which is located on a rich alluvial plain across which the creek flows. This plain lies between the hills of the Coast Range Mountains and the shore of San Francisco Bay. The district covers an area of about 85 square miles much of


ALAMEDA CREEK WATERSHED
LIVERMORE
PLEASANTON
PROPOSED ARROYO VALLE RESERVOIR
PROPOSED SAN ANTONIO RESERVOIR
CALAVERAS RESERVOIR
SAN JOSE
ALAMEDA CREEK
NILES CONE
NEWARK
HAYWARDS
SAN LEANDRO
SO. PAC. R.R.
OAKLAND
ALAMEDA
SAN FRANCISCO BAY
SAN FRANCISCO
SPRING VALLEY PIPE LINES
SAN MATEO
REDWOOD
MENLO PARK
PALO ALTO
PACIFIC OCEAN
STATE WATER COMMISSION
SKETCH MAP OF
NILES CONE AND ALAMEDA CREEK WATERSHED
SCALE
1920
Note: The area affected by conveyance of water rights to the Spring Valley Water Company is shown in solid black

which is very highly developed. The towns of Niles, Centerville, Irvington, Newark, Alvarado and Decoto lie within its boundaries. Spreading out between these towns is an intensively farmed area of very high land values. Irrigation is practised from wells which dot this rich alluvial plain, commonly known as the "Niles Cone," adding greatly to is productivity. The water supply for the city of Haywards and a portion of that for Oakland is pumped from wells in this area. There is also a considerable use of water from wells for industrial and domestic purposes within the district. All told the annual draught upon the underground waters of this area is about 18,000 acre feet. It is claimed that the interference with the natural flow in the creek, by the proposed storage and additional diversion on the upper watershed, will diminish the annual replenishment to these underground waters and hence deprive the people of the district of their rights to the percolating waters which have their origin in the natural flow in the creek channel.

The investigation of the interference of these proposed diversions upon the replenishment of the underground water of the Niles Cone was a problem in percolating water extending into the realms of science which had been little explored. The volume and rates of percolation from the creek channel under the various natural conditions of flow in the creek had to be determined in such a way that the effect of decreasing this flow by diversions on the upper watershed could be ascertained. The water percolating from the creek channel then had to be traced underground to find its relation to the replenishment of the well supply in the district.

The engineering investigations were divided into two distinct endeavors: first, to measure the percolation from the creek channel and establish from these measurements the manner in which the rate of percolation varies with influencing factors; and second, to determine the sources of supply and the draughts on the underground waters supplying the wells in the Alameda County Water District.

Measurement of Percolation From the Channel of Alameda Creek.

The percolation from the creek channel was measured as the difference in flow between a point upstream from the head of the cone and one at its lower end. Two current meter gaging stations were established for this purpose, the upper one in Niles Canyon just above the point where the creek emerges from the hills, and the lower one as near the bay shore as was practical to measure the stream. The most precise record possible of the stream flow past these two stations was maintained during the entire period of investigation. The many difficulties encountered in obtaining the precision necessary to define the rates of percolation with surety required an extension of the standard

methods of stream gaging and analysis of data. Each process in the work was carefully analyzed from the basic principles of science and such experimental and test data was taken as was necessary to prove out the way.

Alameda Creek presents practically all the obstacles to accuracy in stream gaging known to the science of hydrography. The flow in the creek is very flashy. It drains a large watershed covering about 640 square miles upon which there is ordinarily no snowfall. Precipitation occurs as rain falling on fairly steep slopes the surface of which becomes unabsorbent after being wet by the first rains of the season. Runoff therefore follows quickly after rainfall, and the high flows are confined largely to periods during or immediately following storms. The rises are very rapid and often reach a peak flow of several thousand second feet in a few hours. The maximum flood flow is estimated at about 20,000 second feet. The peak flow seldom lasts more than an hour or two after which the drop is rapid. The varying confluence of the waters from the several main tributaries of the stream destroys all regularity of flow. This rapid irregularity in discharge coupled with the shifting of the channel with changing flood conditions, make precise gaging most difficult. To meet these conditions it was necessary to devise special equipment for handling the current meter and sounding weights with sufficient speed and accuracy to get results.

The planning of the procedure for these measurements to attain the neeessary accuracy in the results required an investigation and analysis of each step in the work. Much new and interesting information on hydrography was assembled while doing this. The following analyses were completed in great detail insofar as they related to the work on Alameda Creek.

1. Comparison of methods of obtaining the mean velocity in a vertical with a current meter.
2. The favorable number of current meter observations and soundings to a gaging.
3. Favorable time period of observation with a current meter.
4. Effect of vertical speed of integration with a current meter on observed velocity.
5. Rating of current meters.
6. Use of rod floats for gaging low velocities.

On assembly of all the stream gaging data, a study of its accuracy was made and an analysis effected for possible errors. Errors were divided into two classes, compensating and cumulative. So far as it is possible to detect errors by analysis, all except four types of errors were determined to have been reduced to a negligible quantity or to a compensating form on assembly of the entire work. Mathematical discussions were developed of these four types of errors which still remained in the

work, possibly as cumulative errors, and corrections to the work applied accordingly. These discussions involved the working out by principle and the quantitative application to Alameda Creek of the following:

1. Effect of changing stage on station discharge in irregular channels.
2. Effect of turbulent flow on the registry of the Price current meter.
3. Effect of inflow of water to the channel between the gaging station and the point of gage height control on station discharge.
4. Errors in the 0.2 and 0.8 depth method of obtaining the mean velocity in the vertical.

The first three are original research on uninvestigated subjects.

Determination of Rates of Percolation.

With the discharge at the two gaging stations computed, the next task was the derivation of the rates of percolation. Were the flow in the channel steady, the subtraction of the rates of flow at the two gaging stations would yield the rate of loss of flow or the rate of percolation. In this instance it was found that of the two means of escape of the water from the channel, namely by evaporation or percolation, the quantity escaping by evaporation is a negligible quantity in the discussion. Therefore, the entire loss of flow is by percolation. However, observations proved that the flow in the channel is never steady, not even during the very low flows in the late spring which appear to be so steady to the eye. With each fluctuation of flow, either a portion of the water passing the upper station is used for filling the channel to the new flow line on a rising stream, or a portion of the water passing the lower station is supplied from the storage in the channel as it drops to a lower level on a declining flow. A correction for the rate of increasing or decreasing storage in the channel between stations must therefore be made to the subtraction of the rate of flow at the lower station from that at the upper to obtain the rate of percolation.

The storage in the creek channel was computed from field surveys. It requires 1725 acre feet to fill the channel between the gaging stations, or a volume of water equivalent to 870 second feet flowing for 24 hours. With the rapid change in gage height which normally occurs during flood periods, it is seen that several hundred second feet may be entering or leaving storage for a day or more at a time. The rate of change of storage was found often to exceed the rate of percolation, so that the elimination of the storage effect had to be made with great care. Since the rate of change of channel storage can only be obtained through the time required to fill or empty the channel from one flow

PLATE XVI.

Water stage register at well on Niles Cone recording fluctuations of level of underground water.

line to another, a period of time had to be selected for the determination of the rates of percolation. The shorter this time period might be taken, the greater its average rate of change in channel storage, and hence, the more difficult its determination with precision relative to the rate of percolation. On the other hand, the longer this time period might be taken, the less it could be expected to discover the manner of variation of the rate of percolation which would then appear as an average value in the results. The day of 24 hours was finally selected as the practical unit of time for the study. The mean daily percolation was therefore computed for every day of the entire investigation by adding to or deducting the average rate of change in channel storage from the difference in mean daily discharge at the two gaging stations.

The rate at which water was entering or leaving storage for the day was determined by a graphic method of integration. The discharge records of both gaging stations were plotted on identical time and discharge scales. The rising and falling stages at the upper station were divided into increments of change of convenient dimensions. The time required for each increment of change in flow to reach the lower station was shown on these plots by the horizontal ordinate between the portions of the hydrographs at the two stations which were cut by the horizontal lines bounding the arbitrarily selected increment at the upper station. The volume of water shown by the field surveys to be required for filling between the upper and lower flow line of this increment, divided by the time as shown by the horizontal ordinate between the two hydrographs, gave the average rate at which the water was filling or emptying that increment of storage. The rate at any time at which water was going into or out of storage in the entire channel between gaging stations was then the algebraic sum of all the rates at which increments of storage were being filled or emptied at that particular time. These rates were summed for convenient time periods and then averaged for the day. In order to accurately show the difference in flow at the two stations on the graphs on which this work was carried out, it was necessary to use a very large scale. Many of the drawings were 8 to 10 feet high and had to be constructed in sections. This added materially to the difficulties in the detail execution of this work.

Manner of Variation of Rates of Percolation.

With the tabulation of the mean daily flow in the channel and the mean daily rates of percolation completed, search was commenced for an expression of the manner of variation of the rate of percolation with the flow in the creek channel and other factors influencing it. A mathematical formula expressing this relationship was developed as described

in the letter of October 20, 1920, to the Commission, which is incorporated in the "Final Determination" of the Commission appearing in Appendix F of this Report.

Supply and Draught on the Underground Waters of the Niles Cone.

A very comprehensive study was conducted of the sources and volume of the supply and draught on the underground water of the Niles Cone, and of the movement of the percolating water. For this purpose, measurements to water level were made in a large number of wells. Differential levels were run between the wells so as to express the results of the measurements in elevations of the water surface. Much well data was also obtained from previous investigations on the cone by other parties. All this information was plotted in graphs resulting in the delineation of the hydrographs of 418 wells extending over the period from the fall of 1913 to the fall of 1919.

The well hydrographs yielded much information upon supply and movement of the underground waters of the cone. It is observed on a comparison of these hydrographs that the water levels in the wells fluctuate in yearly cycles, rising in the winter and spring and receding in the summer and fall. These cycles are approximately coincident with or subsequent to the cycle of flow in the creek in their main features. When superimposed one on the other, definite time intervals are shown between the seasonal cycle of successive wells. Where the well records are complete and the hydrograph undistorted by pumping draught, this time interval seems to be about the same for all years. A study of this movement shows that, in general, these cycles progress on lines radiating from the creek channel and move outwardly quite rapidly. Within 15 days the wave of seasonal rise has spread over practically the entire head of the cone and in 40 days it has spread over the whole area under influence of the percolation from Alameda Creek.

This strong sympathetic behavior of the wells with the flow in Alameda Creek and the consecutive movement of the wave of influence radiating outward from the creek channel indicates that the percolation from the channel of Alameda Creek is the principal source of replenishment to the underground waters of the cone. However, several other minor sources of supply are possible in the percolation from the surface and underflow from adjacent hill drainage and in the direct percolation of rainfall and irrigation water. The replenishment which the underground waters of the cone receive from these minor sources of supply must necessarily be in small quantities, since they have no noticeable effect on the cyclic behavior of the well hydrographs. If large quantities were involved it is obvious that some effect

would be displayed on these hydrographs. Based on such data as could be obtained, it was estimated that the total annual replenishment from all these sources is about 5 per cent of the percolation from Alameda Creek.

A very careful investigation was made of the penetration of the direct rainfall on the cone. There are almost no signs of surface runoff, so that rain falling directly on the cone must either be absorbed by the ground or evaporated into the atmosphere. Should any of the rainfall which is absorbed by the ground percolate beyond the depth from which capillary action of the soil can draw it back to the surface, it must ultimately join the ground water. In order to determine whether or not any rainfall percolates below the depth of capillary action, four test tanks were constructed and observed for two seasons.

Believing that the results of past measurements of rainfall percolation are of doubtful significance because of the disturbance of the soil in the construction of the tanks, special attention was given to obtaining measurements on an undisturbed soil column. The tanks were constructed by lowering a 30-inch riveted steel pipe over a column of soil in its natural state. This soil column was trimmed to a diameter of 27 inches as a pit was excavated around it. The column was tightly wrapped with canvas strips to hold it intact, while the pit was being dug around it and the pipe lowered into place. The pipe was suspended from a tripod and lowered over the soil column as the work progressed. This gave protection and lateral support to the column which preserved it from disturbance during the progress of the work. When full depth was reached, the annular ring between the soil column and the pipe was poured full of hot tar. Test holes were bored in the side of the pipe to inspect the distribution of this tar. It was found to have filled the space perfectly without penetration of the soil.

The limiting depth of capillary draught to the surface being ordinarily conceded to be about 8 or 10 feet, the depth of these tanks was made 15 feet. The bottoms of the tanks were made of a three-eighths inch steel plate which was jacked into place under the column hard up against the pipe. The joint between the pipe and the plate was made by pouring a thick ring of tar around the bottom of the pipe and resting on the extending edges of the plate. A two inch perforated drain pipe was inserted into the bottom of the column to collect any water which might percolate to the bottom of the tank. This drain pipe leads through the tar joint between the plate and the pipe to a small collecting tank set in the ground below the main tank. Two riser pipes extend from this collecting tank to the ground surface through which a measurement of the amount of water draining into the collecting tank can

be made. After heavily tarring all joints, the excavation was backfilled to ground level.

The four tanks were located in different parts of the cone each one in a typical soil column as near as could be determined by making a number of scattered borings over the cone.

The average rainfall on the Niles Cone varies from 15 to 20 inches. The heavier rainfall is close to the hills and the lighter in the lee of the Coyote Hills along the bay shore. The first season of exposure the tanks had from 9.35 to 10.42 inches of rain fall on them. The second winter from 16.91 to 20.19 inches fell on them. No water penetrated in any column to the bottom of the tank. In addition to the natural rainfall two of the tanks were given a six inch irrigation in the second summer. Even this did not penetrate the columns. It was therefore concluded that there was no replenishment to the ground water from the direct percolation of rainfall in the ordinary year or from the usual application of irrigation water. It was observed in the construction of the tanks and in the borings of the survey for their location, that the soil columns were fairly uniform in type and of a silty or clay loam which has a strong capillary power for raising water. It is probable that this strong capillary power of the soil drew the water which penetrated the soil back to the ground surface to evaporate before it reached a depth below which it could not return. In order that the evaporation from the ground surface in the tanks should be similar to that in the fields, the surface of the tanks were kept mulched to the same degree as the adjacent fields.

Investigation of the draughts from the underground waters of the Niles Cone showed that a very large volume of water is annually pumped from wells. There are about 1450 wells within the area of influence of Alameda Creek of which about 300 are used for irrigation, 80 for industrial and 50 for public water purposes. The remainder are domestic or stock wells.

An intensive study of the draught from these wells and the use to which the water was put, was made through the year 1917. For this purpose, the output of every individual well of any importance was measured and a special field canvass made to determine the use of the water. The output from the electrically driven plants was computed from the consumption of electric energy recorded on the meters. In this work complete field tests were made on 91 electrically driven pumping plants and incomplete field tests on 26 others. The output from the gasoline driven plants was estimated by means of field measurements of the discharge and time records of operation. The discharge was measured on 95 plants. The time records of operation were kept by the plant operators. Direct measurements of this character were made

either by the Commission or by private parties who furnished the data to the Commission, on about 90 per cent of the total water pumped from wells during 1917. The remaining 10 per cent was estimated from data obtained by special inquiry.

The draught on the wells both prior and subsequent to 1917 was estimated based on the work of 1917. For all electrically driven pumping plants, the meter records of power consumption and the pumping plant tests made in 1917 furnished the basis for the computations. For the gasoline driven plants the measured duty of water in 1917 and statements of the areas and crops irrigated obtained from the operators of the properties, furnished the basis of computations. The water exported and a portion of the industrial and domestic uses were obtained from the direct measurements by other parties as in 1917. The rest was estimated from miscellaneous data obtained through special inquiry.

Other minor draughts on the underground waters were found to be the flow from artesian wells, the flow from natural springs, the evaporation and transpiration of water brought to the surface of the ground or zone of plant roots by capillary action of the soil, or by artesian pressure, and leakage into the bay. In past years these draughts totaled a very considerable volume of water. There formerly existed an artesian pressure of from 10 to 15 feet, in a strip of territory several miles wide along the bay shore. This pressure caused the escape of a large volume of water through uncapped artesian wells and springs which water worked off through the marshes to the bay. In recent years, the pressure level of the underground waters of this area has declined to a position several feet below the ground surface, so that the flow from wells and springs is now a very nominal quantity. The position of the water table for the last few years is such that the evaporation and transpiration from the ground surface and from the plant growth along the bay shore is a small draught. A careful estimate of the quantity of this draught was made, based on investigations in other localities.

Balance of Inflow to and Draught From the Underground Waters of Niles Cone.

The water level in the wells of the Niles Cone stood at a low level during the summer and fall of 1913. During the next three years, there was abundant replenishment to the underground waters and the well levels rose considerably. The recharges to the underground waters of 1917 and 1918 were not sufficient to maintain the higher levels, however, so that by the fall of 1918, the well levels in most of the district had returned to almost the identical levels of the fall of 1913.

This natural cycle of the ground water elevations covering a five year period affords an excellent opportunity to compare the inflow to and draught from the underground storage without the uncertainty of computing the change in storage between the beginning and end of the period. As determined by these investigations, the total replenishment during this five-year period was 79,500 acre feet. The total draught during the same period was 88,100 acre feet. These two figures should be equal except for any difference in storage in the underground gravels that might exist between the beginning and end of the period. The water level over a portion of the cone stood a little higher in the fall of 1918 than in the fall of 1913. It was estimated on a basis of measured percolation and its effect on well levels that there were about 1600 acre-feet more storage in 1918 than in 1913. The discrepancy in the estimation of the inflow to and the draught from the underground water of the Niles Cone for the five-year period is then 10,200 acre-feet or 13 per cent of the volume measured.

APPENDIX F.

FINAL DETERMINATION IN THE CONTROVERSY BETWEEN ALAMEDA WATER DISTRICT AND SPRING VALLEY WATER COMPANY REGARDING THE WATERS OF ALAMEDA CREEK.

SAN FRANCISCO, CALIFORNIA.
December 28, 1920.

Alameda County Water District,
San Francisco, California.

Spring Valley Water Company,
San Francisco, California.

FINAL DETERMINATION.

GENTLEMEN: By agreement dated September 1, 1916, the Alameda County Water District (hereinafter called the district) and the Spring Valley Water Company (hereinafter called the company) submitted to the undersigned (hereinafter called the board), then the appointed members of the State Water Commission, a controvery regarding the diversion and storage of the waters of Alameda Creek in Alameda County, California.

The preamble to the agreement, in part, recites that the company is supplying water to the city and county of San Francisco, and for this purpose has been taking water from Alameda Creek; that for the purpose of augmenting its supply, it is now constructing the Calaveras reservoir on Calaveras Creek, a tributary of Alameda Creek; and proposes to construct other reservoirs on other tributaries; that the district includes land in Alameda County lying on both sides of Alameda Creek westerly from the town of Niles and below the point of diversion of water from Alameda Creek by the company; that it is claimed that the lands in said district, in whole or in part, are underlain by water-bearing strata which are supplied in whole or in part by waters of Alameda Creek, and that the augmenting of the amount of water taken by the company from said creek, or its tributaries, will lessen the supply of water in said strata with resultant damage to the owners of overlying lands; and that the district has brought suit to restrain the company from maintaining reservoirs on Alameda Creek or its tributaries, and from increasing the amount of water diverted by it from said creek or its tributaries.

PLATE XVII.
Current meter reel at upper measuring station on Alameda Creek.

The preamble continues as follows:

WHEREAS, There are frequently large amounts of water which pass down Alameda Creek into the bay of San Francisco and are not conserved, and which it is claimed are not put to beneficial use; and the water district and the water company have been conferring for the purpose of reaching, if possible, without further litigation, a settlement, fair both to the landowners and inhabitants of the water district and to the water company, of the conditions upon which the water company may construct and use storage reservoirs on Alameda Creek and its tributaries and increase the amount of its diversion therefrom by the conservation and use of the said waters which are not now conserved, and which it is claimed, as aforesaid, are not put to beneficial use; and

WHEREAS, The parties have been unable to agree upon the terms of such settlement by reason of the lack of physical data necessary for a fair consideration of all the plans of settlement suggested, or for an intelligent and fair solution of all of the questions involved, and it is desired to obtain such data under the direction of some competent and disinterested board, and when it is obtained to have a decision as to what is a fair and reasonable settlement, and the three appointed members of the State Water Commission have expressed their willingness to accept the direction of the work of gathering such data and to endeavor to decide as to such settlement.

The agreement provides that for a period of three years from date thereof, the board shall direct the work of obtaining physical data deemed necessary to an "intelligent and fair determination of the conditions upon which the water company may, with due regard to the rights of landowners within the water district, store water on Alameda Creek and its tributaries and increase the amount of its diversion therefrom." The agreement further provides that the said work shall be done at the sole expense of the company.

Paragraph II of the agreement is as follows:

"Upon the completion of said three (3) year period, or earlier, in case it concludes it has sufficient data, the State Water Commission shall proceed in conference with the parties to fix and determine the terms and conditions, in accordance with the character of the particular season, upon which such storage and additional diversion may be made, provided, however, that such settlement shall not, without the consent of the parties hereto, prescribe a settlement by surface irrigation or other means of supplying water within the water district other than from the water-bearing gravel strata heretofore mentioned, the differences between the parties hereto being confined to the questions of the effect of the storage and additional diversion contemplated by the water company upon such water-bearing strata and resultant damage therefrom to lands within the water district underlain by such strata, and the respective rights in connection therewith of the parties hereto and of those for whom they are, respectively, acting, it being the object hereof to reach a settlement whereby, in the most economical and practical manner, it shall be made possible without further litigation to conserve and put to beneficial use the waters of Alameda Creek and its tributaries, which are now not put to use, and at the same time to prevent any damage being done thereby to those lands which are underlain by water-bearing strata supplied in whole or in part from Alameda Creek, or, if it is not possible to prevent such damage entirely, to compensate the owners of said lands to the extent to which such damage is not prevented, the making of such compensation by the water company, if it be provided for by such settlement, to be a condition of the exercise by the water company of any rights or privileges accorded to it by such settlement.

The settlement so fixed and determined by the State Water Commission shall be final and conclusive upon the parties hereto, but the water company shall not be deemed to waive any existing rights which it may have acquired against particular landowners or particular lands within the water district (the water district, however, not conceding that any such rights or claim are binding upon it), and the settlement awarded by the State Water Commission shall be subject to such particular rights so far as such rights may exist."

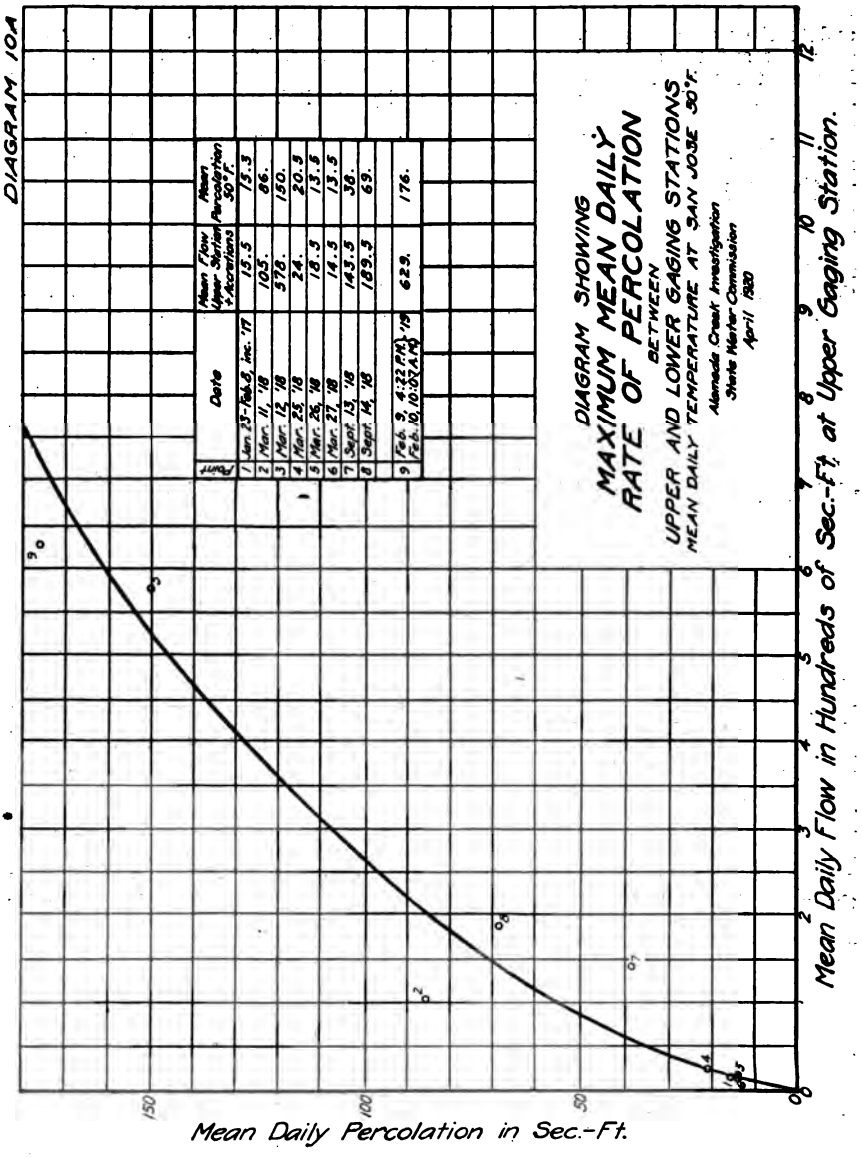


DIAGRAM 10A
DIAGRAM SHOWING
MAXIMUM MEAN DAILY
RATE OF PERCOLATION
BETWEEN
UPPER AND LOWER GAGING STATIONS
MEAN DAILY TEMPERATURE AT SAN JOSE 30°F.
Alameda Creek Investigation
State Water Commission
Apr-11 1920
Date
Mean Flow Upper Station + Accretion
Mean Percolation 30°F.
1 Jan 25-Feb 6, inc. '17 13.5 13.5
2 Mar. 11, '18 105. 86.
3 Mar. 12, '18 378. 150.
4 Mar. 23, '18 24. 20.5
5 Mar. 26, '18 18.5 13.5
6 Mar. 27, '18 14.5 13.5
7 Sept. 13, '18 143.5 36.
8 Sept. 14, '18 189.5 69.
9 Feb. 9, 4:22 P.M. '19 to Feb. 10, 10:05 A.M. '19 629. 176.
Mean Daily Percolation in Sec.-Ft.
Mean Daily Flow in Hundreds of Sec.-Ft. at Upper Gaging Station.

In accordance with the conditions of the agreement, the board placed Mr. Paul Bailey, an engineer of the State Water Commission, in charge of the work of assembling physical data contemplated by the agreement. The field work covered the runoff season of 1916–1917, 1917–1918 and 1918–1919. At the end of each season a report was prepared by Mr. Bailey and copies thereof given to the parties. The following is a list of the reports so submitted:

October 16, 1917—"Stream Gagings and Percolation Losses," 1916-1917, accompanied by: 1. Field notes and computations—stream gagings; 2. Recording gage records—stream gagings.

May 29, 1918—Compilation of well data on Niles Cone to January 1, 1918, presenting measurements of Alameda County Water District, Spring Valley Water Company and State Water Commission plotted to the same datum.

April 5, 1919—"Stream Gagings and Percolation Losses," 1917-1918, accompanied by: 1. Field notes and computations—stream gagings; 2. Recording gage records—stream gagings.

November 21, 1919—"Pumping Draught and Irrigation from the Underground Water of the Alameda County Water District."

February 3, 1920—"Hydrographs of Wells in the Alameda County Water District," 1913-1920.

February 26, 1920—"Stream Gagings and Percolation Losses," 1918-1919, accompanied by: 1. Field notes and computations—stream gagings; 2. Recording gage records—stream gagings.

June 3, 1920—"Engineer's Report on Investigations on the Niles Cone," 1916-1920.

The work performed under the direction of Mr. Bailey represents the most intensive and careful stream-gaging work ever done in the Western States, and probably in the entire country. Mr. Bailey introduced new mechanical methods to facilitate work at the stream-gaging stations and assembled the field data in such excellent form that the engineers of the parties freely commend his accomplishment.

After the submission of Mr. Bailey's report of June 3, 1920, the parties were asked to submit comments on said report to the board. In accordance with said request, the company submitted its comments by a letter dated July 2, 1920, signed by G. A. Elliott, chief engineer, and by letter dated July 3, 1920, signed by J. B. Lippincott. On July 15, 1920, an informal meeting was held at which were present the board and representatives of the parties. The parties were requested to submit their suggestions as to a solution of the problem, in addition to their comments on Mr. Bailey's report. In accordance therewith, the company submitted its suggestions as to a solution by letter dated August 16, 1920, signed by G. A. Elliott, chief engineer, which letter was accompanied by a report on the "Necessity for the Conservation of the Water Supply of California," by J. B. Lippincott. The district submitted its comments upon the Bailey report by letter dated September 15, 1920, signed by Cyril Williams, Jr., manager of the district.

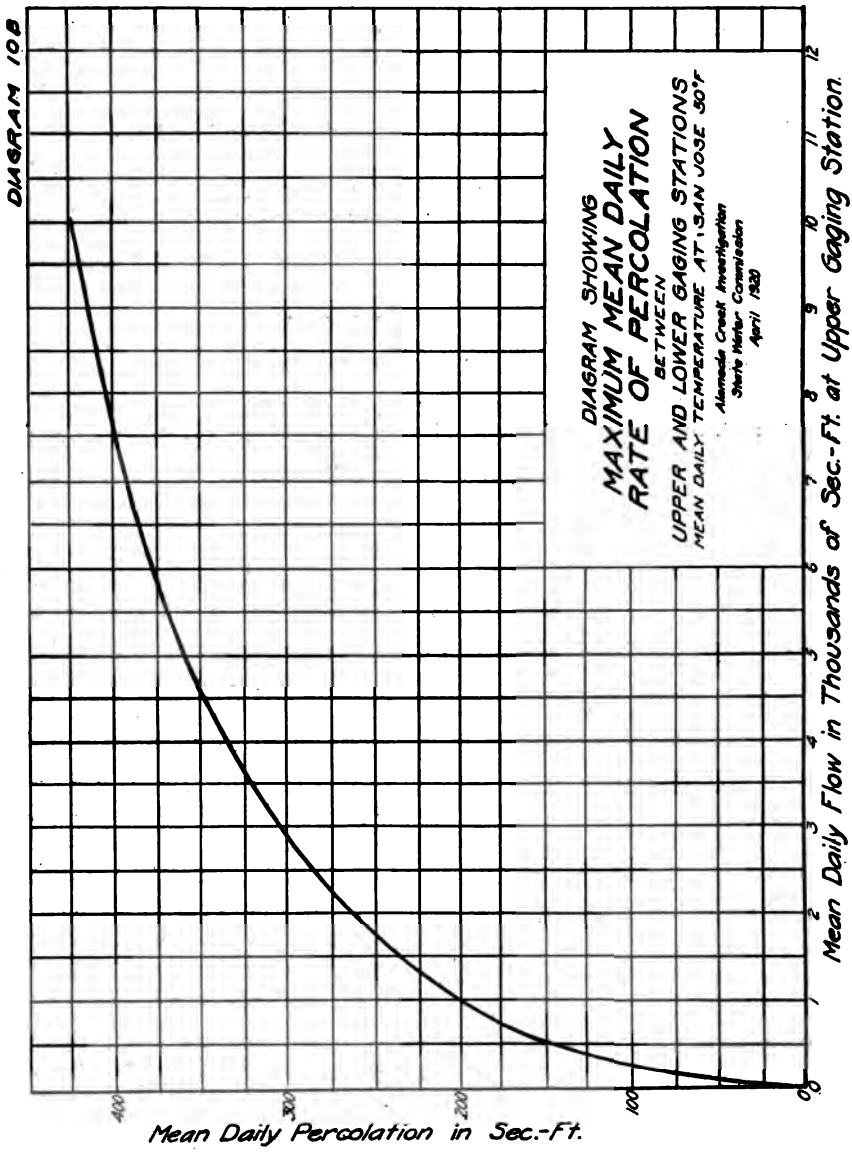


DIAGRAM 108
DIAGRAM SHOWING
MAXIMUM MEAN DAILY
RATE OF PERCOLATION
BETWEEN
UPPER AND LOWER GAGING STATIONS
MEAN DAILY TEMPERATURE AT SAN JOSE 50°F
Alameda Creek Investigation
State Water Commission
April 1930
Mean Daily Percolation in Sec.-Ft.
0
100
200
300
400
Mean Daily Flow in Thousands of Sec.-Ft. at Upper Gaging Station.
1
2
3
4
5
6
7
8
9
10
11
12

It submitted its suggestions as to a solution by letter dated September 16, 1920, signed by J. A. Shinn, president of the district.

On October 21, 1920, a meeting was called by the board at which were present representatives of the parties. The suggestions of the parties were informally discussed and Mr. Bailey presented, by letter dated October 20, 1920, his suggestions for the solution of the problem. The parties were requested to submit final suggestions by November 15, 1920.

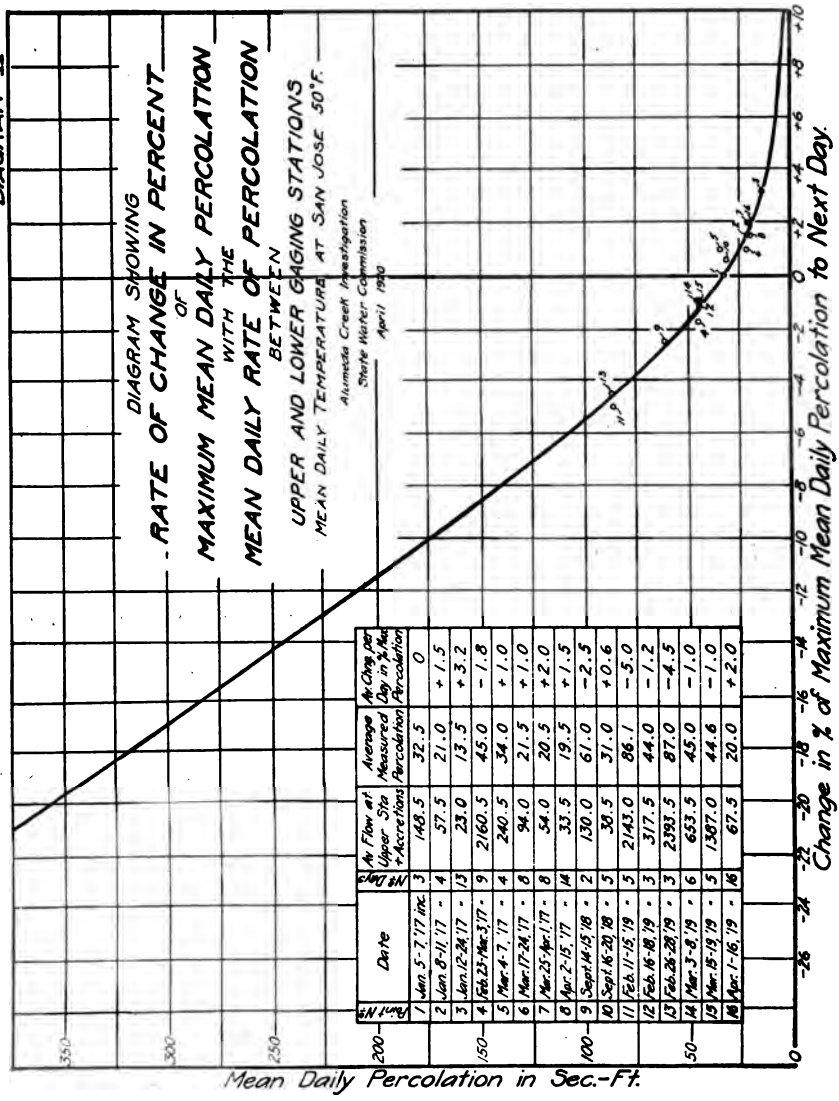
In accordance with the request, the district submitted a review of the reports of Mr. Bailey, Mr. Elliott and Mr. Lippincott, by letter dated November 15, 1920, signed by Cyril Williams, Jr., engineer and manager of the district, and a statement of legal points by letter dated November 15, 1920, signed by Elston, Clark and Nichols, attorneys for the district. The company submitted its comments by letter dated November 15, 1920, signed by G. A. Elliott, chief engineer, and McCutcheon, Willard, Mannon and Greene, attorneys for the company. The attorneys for the company submitted, under date of November 19, 1920, further comments on the letter of November 15th from the attorneys of the district.

SOLUTION SUGGESTED BY THE DISTRICT.

The solution suggested by the district is fully set forth in the following paragraph from its letter of September 16, 1920:

"The district submits, as the conditions under which diversion of water from Alameda Creek and its tributaries may be made by the Spring Valley Water Company under the contract of September 1, 1916, the following: Unless such flow from the Alameda Creek watershed as is in excess of that flow which is diverted or stored by the Spring Valley Water Company produces and maintains the levels of water in the gravels of the Niles Cone, as they existed in the year 1914, the Spring Valley Water Company shall produce and maintain such levels for each year by cessation of diversion, release of waters and the construction and use of such reservoirs, dams, or other artificial means as may be necessary."

It is believed that no controversy over the use of water can be equitably adjusted by the maintenance of water levels, in cases where such levels are being lowered by pumping from the source of supply. An excellent illustration of an instance where such adjustment is possible is the controversy existing over the waters of Lake Tahoe, between the United States Reclamation Service and the marginal owners. Lake Tahoe is principally valuable to the marginal owners for purposes of navigation. They do not desire to deplete the waters of the lake by pumping from it. It is, therefore, possible to agree upon the limits of lake elevation within which the surface of the lake must be maintained. As stated, such an arrangement can not be equitably made where the waters are being directly taken by the marginal owners, as



No. Days	Date	No. Days	Av. Flow at Upper Sta. +Accretions	Average Measured Percolation	Av. Chng. per Day in % Max. Percolation
1	Jan. 5 - 7, '17 Inc.	3	148.5	32.5	0
2	Jan. 8-11, '17 -	4	57.5	21.0	+ 1.5
3	Jan. 12-24, '17 -	13	23.0	13.5	+ 3.2
4	Feb. 23-Mar. 3, '17 -	9	2160.5	45.0	- 1.8
5	Mar. 4-7, '17 -	4	240.5	34.0	+ 1.0
6	Mar. 17-24, '17 -	8	94.0	21.5	+ 1.0
7	Mar. 25-Apr. 1, '17 -	8	54.0	20.5	+ 2.0
8	Apr. 2-15, '17 -	14	33.5	19.5	+ 1.5
9	Sept. 14-15, '18 -	2	130.0	61.0	- 2.5
10	Sept. 16-20, '18 -	5	38.5	31.0	+ 0.6
11	Feb. 11-15, '19 -	5	2143.0	86.1	- 5.0
12	Feb. 16-18, '19 -	3	317.5	44.0	- 1.2
13	Feb. 26-28, '19 -	3	2393.5	87.0	- 4.5
14	Mar. 3-8, '19 -	6	653.5	45.0	- 1.0
15	Mar. 15-19, '19 -	5	1307.0	44.6	- 1.0
16	Apr. 1-16, '19 -	16	67.5	20.0	+ 2.0

the amount so taken might, in many seasons, be in excess of the amount of inflow.

As the district has been organized to increase its avaiable water supply, it is not unlikely that it will at a later period desire to store water on some tributary of Alameda Creek which traverses part of the Livermore Valley. As the owners of land within the Livermore Valley are now pumping from the underground supply, it is evident that the District could not agree upon a maintenance of water levels at some fixed elevation and allow the landowners within the Livermore Valley to increase their diversion from the underground supply at will.

The inequity of such an arrangement is apparent from the following figures taken from Mr. Bailey's report. The draft on the underground waters of the district, by pumping from wells for irrigation, domestic water supply and industrial purposes totaled about 6100 acre-feet in 1900; 8800 acre-feet in 1909, 15,900 acre-feet in 1916, and 18,000 acre-feet in 1919. The amount of percolation from Alameda Creek into the district in 1916–1917 was 13,660 acre-feet; in 1917–1918, 5720 acre-feet; 1918–1919, 11,660 acre-feet—these figures representing the amount of percolation between gaging stations as given by Mr. Bailey's formula, plus ten per cent allowed for percolation below lower gaging station and from Crandall Slough, plus percolation from stored water released from Calaveras reservoir in amount equal to that withheld from the gravels by the season's storage as given by Mr. Bailey's formula. The amount of water pumped from underlying strata was, therefore, in excess of the amount of water which percolated into such strata from Alameda Creek under the natural conditions of flow as determined by Mr. Bailey's investigations.

In its letter of September 16, 1920, the district further states:

> * * * that the district and the landholders thereof should not be deprived of the right to have the waters of Alameda Creek flow down through the district in the great quantities ordinarily assured by natural conditions * * *.

The essence of the purpose of the investigation is to state "the conditions upon which the water company may, with due regard to the rights of landowners within the water district, *store water on Alameda Creek and its tributaries and increase the amount of its diversion therefrom.*" To "have the water of Alameda Creek flow down through the district in the great quantities ordinarily assured by natural conditions," would preclude any possibility of storage or increased diversion from the creek and nullify the purposes of the agreement and investigation.

In the letter of the attorneys of the district dated November 15, 1920, the case of *Miller* vs. *Bay Cities Water Company,* 157 Cal. 256, is cited as authority for the following principle:

"They (the owners of overlying lands) have the right to the flow of the storm waters though parts thereof run to the bay."

The Bay Cities case deals with a state of facts so extreme that Mr. Justice Shaw, in a concurring opinion, said—

"The Santa Clara Valley presents conditions not paralleled elsewhere in the state, except it may be in the San Fernando Valley, in which is found similar gravel beds kept supplied by similar flood waters and rainfall, the use of which water is secured to the city of Los Angeles by its ancient pueblo right, * * * the floods from which it can be asserted with any reasonable assurance that waste occurs, are infrequent. They come at intervals of several years and generally the waste water is practically indeterminable."

The conditions existing on Coyote Creek as found by the court in the Bay Cities case are entirely different from those existing on Alameda Creek. Undoubtedly the attorney for the district had this difference well in mind when he advised the execution of the agreement of September 1, 1916. The execution of the agreement by the district makes the consideration by the board of this legal point unnecessary, but in referring to it the board desires to emphasize the public need of storage reservoirs in this state. Applications have been made by irrigation districts now existing, or by the proponents of districts to be formed, for storage reservoirs on practically every stream of importance in the San Joaquin and Sacramento Valleys and on other streams elsewhere in the state. On the valley floor between the main streams in the Sacramento and San Joaquin Valleys is a large and rapidly increasing number of pumping plants used for irrigation purposes. If the principle cited as the principle of the Bay Cities case was of general application, the proposed appropriation for storage purposes by the many irrigation districts would have to be denied by the State Water Commission. That such is not the principle of general application is shown by the following excerpt from the case of *Miller and Lux* vs. *Fresno Flume and Irrigation Company,* 158 Cal. 626.

"In *Miller* vs. *Bay Cities Water Co.*, 157 Cal. 256 (107 Pac. 115), the principle is clearly recognized and declared that an appropriator of water may divert for use to any point beyond the watershed any portion of the waters of the stream which serves no useful purpose either to the riparian owners, or in supplying the underground stratum, or such waters as are in excess of the quantity necessary for such purposes."

In the Bay Cities case, the Supreme Court of California rests its opinion on its reversal of the common law rule regarding the use of percolating waters in *Katz* vs. *Walkinshaw,* 141 Cal. 116. The theory for such reversal is the need of greater conservation in the use of waters in so arid a State as California. It would be most repugnant to

public policy if a principle originally established as a guide to true conservation should be made the basis of a rule of ruthless waste. This is evident from the following excerpt from the opinion of the California Supreme Court in *Burr* vs. *Maclay Rancho Water Company,* 154 Cal. 428, wherein at page 436 it is said:

"In the case of either class of owners of overlying lands, the appropriator for use on distant land has the right to any surplus that may exist. If the adjoining overlying owner does not use the water, the appropriator may take all the regular supply to distant land until such landowner is prepared to use it and begins to do so. It is not the policy of the law to permit any of the available waters of the country to remain unused, or to allow one having the natural advantage of a situation which gives him a legal right to water to prevent another from using it, while he, himself, does not desire to do so. The established and settled law of riparian rights in running streams, which have become vested rights, may compel a different rule with regard to such waters in some instances, but these rules of law do not, of necessity, control rights in percolating waters. The most that should be allowed in such circumstances is to give a party the aid of the courts to protect his right and prevent the destruction of his source of supply by excessive use or other cause. The court unquestionably has power to make reasonable regulations for the use of such water by the respective parties, fixing the times when each may take it and the quantity to be taken, provided they be adequate to protect the person having the paramount right in the substantial enjoyment of that right and to prevent its ultimate destruction."

In consideration of the above the board commends the action of the district in executing the agreement, as such action is directly in line with proper public policy.

SOLUTION SUGGESTED BY THE COMPANY.

The solution suggested by the company is concisely stated in the following quotation from pages 6 and 8 of letter dated August 16, 1920, and signed by G. A. Elliott, chief engineer:

"The essential question is to determine what additional amount of water would have been added to the underground supply of the cone if the water stored in the reservoirs of the Spring Valley Water Company had been allowed to flow across the cone and mingle with the remaining natural flow of the stream in any particular season. In other words, how much water was kept out of the cone as a result of this storage * * *." (Page 6.)

"This indicates pretty definitely that a certain mathematical relation exists between the magnitude of the seasonal flow and the percolation from that flow. If then this straight line, whose direction and location is defined by the three measured seasonal observations, is produced in both directions, it should very closely represent the actual existing conditions for any season so far as the subterranean percolating water supply of the Niles Cone as supplied by Alameda Creek is concerned. The accompanying curve, entitled 'Relation between Absorption into Niles Cone and Runoff of Alameda Creek,' has been constructed on this basis. By the use of this principle, as illustrated by the attached curve, a simple, logical and sound solution for a settlement of the problem is offered. This solution maintains the underground waters of the cone in exactly the same condition that they would be in had no storage existed." (Page 8.)

SOLUTION SUGGESTED BY MR. BAILEY.

Reference has been made to letter dated October 20, 1920, submitted by Mr. Bailey. In it are clearly outlined the steps taken by him in the development of a formula for the determination of losses by percolation

of the waters of Alameda Creek, having given the flow in the creek channel. On first impression the idea of using a formula for the solution of a problem so intricate seems almost ridiculous. Study and consideration, however, carry conviction as to its reasonableness. The curve suggested by Mr. Elliott is a formula in graphical form. Mr. Bailey simply introduces factors, in addition to those used by Mr. Elliott, which seem essential in a final analysis of the problem.

Mr. Bailey's letter of October 20, 1920, is hereby made part of this opinion. His formula is so fully discussed therein that it is unnecessary to expand upon it here. Attention is called, however, to the fact that in the final selection of data, Mr. Bailey found it necessary, for reasons given in his letter, to reject the results of certain measurements, which rejection makes the amount of percolation determined by the formula in excess of the amount shown by actual measurements first reported, as is well illustrated by the following table:

Comparison of Seasonal Percolation Between Gaging Stations by Direct Measurement and by Application of Formula.

Season	Percolation from natural flow in acre-feet				
	Total natural flow acre-feet	Measured	Formula	Increase	Increase in per cent of flow
1916-1917	81,380	7,680	11,570	3,890	4.8
1917-1918	6,900	2,700	3,380	680	9.9
1918-1919	99,980	8,300	10,120	1,820	1.8
Totals	188,260	18,680	25,070	6,390	3.4

It is also important to note that the three-year period of field investigations was one of subnormal runoff and that it included one of the driest seasons known in the history of the state. As subnormal seasons present the acute conditions causing water right controversies, an adjustment based on the conditions occurring in such seasons should afford the greatest possible protection to vested rights. The Niles Cone investigations show that water percolating from the creek channel and remaining in the gravels adjacent to the channel, retards the rate of percolation for additional water. Because of the better opportunity for percolating water to get away from the channel, the ground water table occurring during the natural runoff period of the subnormal seasons of the investigation was therefore productive of more favorable conditions for high rates of percolation from the creek channel than that of seasons of normal runoff would have been.

AREA INFLUENCED BY PERCOLATION FROM ALAMEDA CREEK.

In his letter of August 16, 1920, Mr. Elliott states that consideration should be given to "the fact that the Spring Valley Water Company owns, through purchase, all of the water rights of every sort and nature to 6000±acres of land lying within the boundaries of the Alameda County Water District adjacent to and on both sides of Alameda Creek."

There is attached hereto a map of the district upon which has been marked in blue the area considered by Mr. Bailey as influenced by percolation from Alameda Creek, and upon which has been marked in yellow the area affected by conveyance of water rights to the company, which latter area has been checked by Mr. Bailey and found to be 6080 acres. As the deeds and decrees by which the company secured such rights clearly give the right to the company to store and divert the waters of Alameda Creek as against such lands, they are entitled to no part of the water to be released from storage by the company in accordance with this opinion. To hold otherwise would be to countenance the suggestion that one may convey water rights part and parcel of or appurtenant to his land for valuable consideration, as was the case here, and by the simple method of having his land included in a county water district regain said water rights without returning the consideration.

The necessity of excluding the lands affected by the conveyances to the company from participating in the benefits of released waters is the only reason for considering the area influenced by percolation. The line defining the outer limit of this area has been the subject of much discussion in the arguments presented by the parties. The engineer of the district believes that Mr. Bailey's area is too small and the engineers for the company are equally insistent that it is too large. So eminent an authority as Dr. Branner of Stanford University, in his report to the company dated March 21, 1911, and published in "The Future Water Supply of San Francisco from the Conservation and Use of its Present Resources" by the Spring Valley Water Company, considers the area of influence very much smaller than that fixed by Mr. Bailey.

These conflicting views have been carefully considered by the board. The determination of the dividing line is not subject to exact mathematical precision. As Mr. Bailey has been in such close touch with the problem in living with it in the field for over three years, has made so careful an analysis of the results of his measurements of well water elevations, and has presented his conclusions on so logical a basis, we have accepted his determination as final.

On the map shown in Mr. Bailey's report of May, 1920, following page 142, part of the limiting line of the area of influence was not fixed. On the map herewith the area has been fully closed. It is 36,800 acres. As the area affected by conveyances to the company is 6080 acres, it is 16½ per cent of the entire area of influence.

As the area affected by the conveyances to the company lies along the creek channel, it undoubtedly withholds, for abstraction by pumping, a larger amount of percolating waters than an equal area elsewhere in the area of influence. As no data have been presented with which to definitely weigh the relative degree of productivity of these lands in underground water, no analysis thereof will be herein attempted. The straight percentage of 16½ will, therefore, be used in this final determination.

DILIGENCE IN CONSTRUCTION.

In the letter of November 15, 1920, from the attorneys of the district, it is said:

"When the contract of September, 1916, was made, the construction of a great reservoir system was intended. That has not been built in a reasonable time and never will be built by that company. It is most earnestly urged that the Commission should most carefully guard against a decision purporting to grant that company a lot of rights when it has not and never will comply with the spirit of that contract. A decision which would sweepingly grant to the Spring Valley Water Company a lot of water rights without limit as to the time of construction of reservoirs or works would not be within what the parties to the contract contemplated. And it has doubtless been noted by the Commission that with such construction as has occurred the district, in a year such as had just passed, would be entitled to a very great portion of all the stored waters. The plan was to build reservoirs that would take care of the company's needs and benefit the public. There is now no such plan. They make utterly no suggestion that such is their plan. Nor could such plan possibly be proved to this Commission."

The problem before the board is that presented by the agreement of September 1, 1916. As stated in paragraph I thereof, the problem is to reach "an intelligent and fair determination of the conditions upon which the water company may, with due regards to the rights of land owners within the water district, store water on Alameda Creek and its tributaries and increase the amount of its diversion therefrom."

As previously stated, the preamble recites that the Commission is constructing the Calaveras reservoir and "contemplates in the future the construction of other storage reservoirs on other tributaries of Alameda Creek." If the question of diligence in construction work were to be considered, the various reservoirs would have been definitely described and dates of beginning and completing construction on each unit fixed. No such limitations are found in the agreement.

The agreement contemplates no grant of rights. The solution hereby adopted presents a method for the determination of the amount of

water withheld by storage which, if not so withheld, would percolate into the underground strata within the district. The decision is that the amount so withheld shall be later delivered to said strata to the end that the amount of underground water originating in Alameda Creek and available to lands within the district in any given year shall be the same as it would have been without such storage or increased diversions. If the company constructs no works to store or to divert additional waters, there will, of course, be no need for applying the conditions herein determined.

TIME OF RELEASING WATER FOR PERCOLATION INTO THE GRAVELS OF THE DISTRICT.

In altering the natural regime of percolation from the creek channel by releasing an artificial flow of stored water to percolate into the gravels to make up for the natural percolation withheld from the gravel by storage and additional diversions, it is desirable to make the seasonal cycle substituted for that of nature as similar to it as is possible. The months of large runoff in Alameda Creek are usually January, February and March. Following this flow in the creek there is a pronounced rise in the well levels throughout the district. The investigations show that about forty days are required for the effect of a rise in the creek to spread to all the wells on the cone. The full effect of the natural percolation on well levels, therefore, reaches all parts of the district in the early part of the irrigation season, and the decline in well levels following the cessation of runoff in the creek occurs through the middle of the irrigation season.

In order to avoid waste of water into the bay, the period of time in which the percolation from the artificial flow takes place must be extended to cover a greater period than that of the natural flow. Estimates of the probable quantities of water to be released for percolation and the rates at which it will percolate show that the release should begin in the early winter and continue through all periods during which the creek channel is not filled with natural runoff. By so doing, the quantities of water withheld from percolation may be replaced in the gravels in a manner little different from that in which they would have percolated from the natural runoff. The percolation from the artificial flow by commencing a little sooner and continuing longer into the spring and summer than it would have under natural conditons, produces a less pronounced but a more sustained effect upon the well levels than the same quantity of percolation from natural flow. To accomplish this, the date for commencing release must be set earlier as the capacity of the works constructed by the company to withhold percolation increases. Following such a program, there will be time for the

effect on well levels of the water released in any season to spread through the district before the close of the irrigation season.

In order that the release of water during the natural runoff period will not interfere with the rate of percolation from the natural flow, a short time must be permitted to elapse after each period of natural flow in the creek before release is commenced again. The investigations show that the continuance of flow in the channel fills the adjacent gravels sufficiently to retard the rate of percolation of additional water. By allowing a few days to elapse after a period of natural flow, the gravels adjacent to the channel become cleared of this water which retards the rate of percolation and the channel reaches a condition of maximum receptivity again. In order that percolation from the artificial flow will not reduce this condition of receptivity below the maximum the rate of release during the period of natural runoff must be limited. By so doing, the gravels of the district will always be ready to absorb the greatest possible amount of percolation from natural runoff.

By releasing a portion of the water in the early winter and through the natural runoff period, the company will be enabled to effect a maximum storage in their reservoirs. This course of procedure places part of the draft for applying the district gravels just prior to and during the season in which the water released can be replaced in the reservoirs by catching natural runoff. It is therefore believed that regulation of the release following these principles will operate to the benefit of both the district and company and aid in the conservation of the runoff of the watershed for useful purposes.

CONDITIONS CONTROLLING STORAGE AND ADDITIONAL DIVERSION.

The terms and conditions upon which storage and additional diversion of the waters of Alameda Creek may be made by the company are hereby fixed and determined as follows:

No. 1. The quantity of percolation withheld by reason of such storage and additional diversion shall be ascertained by using Mr. Bailey's formula (page 7 of Mr. Bailey's letter of October 20, 1920), and adding to the result thus obtained ten per cent thereof, to allow for percolation below the lower gaging station and from Crandall Slough.

No. 2. A gaging station will be maintained on Alameda Creek in Niles Canyon satisfactory in location and condition to the Water Resources Branch of the United States Geological Survey. The Geological Survey, in cooperation with the State Water Commission, will make the necessary measurements and calculations to determine the amount of water passing such gaging station. The company shall

furnish the funds necessary to properly maintain such station and to pay for all field and office work in connection with such measurements.

No. 3. The company shall install and maintain a gage in each reservoir, constructed within the watershed of Alameda Creek, to the satisfaction of the Water Resources Branch of the United States Geological Survey, and shall furnish records therefrom to the Geological Survey and to the State Water Commission as desired by said offices.

No. 4. In case an additional diversion is made, in order to determine the amount thereof, the company shall install and maintain such measuring devices as the Water Resources Branch of the United States Geological Survey may require, and shall furnish records therefrom to the Geological Survey and to the State Water Commission as desired by said offices.

No. 5. The company shall release water in such amounts that eighty-three and one-half (83½) per cent of the quanity of percolation withheld by storage and additional diversion in any season, as ascertained under condition No. 1, will be absorbed by the gravels underlying the district. In order that the conditions of release may approach those of nature as nearly as possible, the following regulations of release are prescribed:

(*a*) Prior to completion of construction of 50,000 acre feet of reservoir capacity and additional diversion by the company, the release of water shall commence on January first of any season and continue in sufficient amounts to hold water in the creek channel as far as the town of Alvarado or thereabouts, without a flow past such point, until the volume of water ascertained under condition No. 5 has been supplied to the gravels of the district; provided, that after periods of natural flow in the channel, at least five days shall elapse with an average flow at the gaging station of less than five second feet, or at least ten days shall elapse with an average flow at the gaging station of less than ten second feet before water shall be released for supplying percolation to the district.

(*b*) On completion of construction of 50,000 acre feet of storage and additional diversion, and prior to completion of 100,000 acre feet of storage and additional diversion, the release of water shall commence on December first of every season and continue in sufficient amounts to hold water in the creek channel as far as the town of Alvarado or thereabouts, without a flow past such point, until the full volume of water ascertained under condition No. 5 has been supplied to the gravels of the district; provided, that after periods of natural flow in the channel, at least five days shall elapse with an average flow at the gaging station of less than five second feet, or at least ten days shall elapse with an average flow of less than ten second feet, before

water shall be released for supplying percolation to the district; and provided further, that the rate of release during the months of December, January, February and March shall not exceed 20 second feet measured at the gaging station; and provided, further, that the percolation occurring from released water during the month of December shall not be deducted from the volume of water due the district until the following March first.

(*c*) On completion of construction of 100,000 acre feet or more of storage and additional diversion, the release of water shall commence on November first of every season and continue in sufficient amounts to hold water in the creek channel as far as the town of Alvarado or thereabouts without a flow past such point, until the volume of water ascertained under condition No. 5 has been supplied to the gravels of the district; provided, that after periods of natural flow in the channel at least five days shall elapse with an average flow at the gaging station of less than five second feet, or at least ten days shall elapse with an average flow of less than ten second feet before water shall be released for supplying percolation to the district; and provided, further, that the rate of release during the months of November, December, January, February and March shall not exceed 20 second feet, measured at the gaging station; and provided, further, that the peroclation occurring from released water during the months of November and December shall not be deducted from the volume of water due the district until the following March first.

W. A. JOHNSTONE.
IRVING MARTIN.
A. E. CHANDLER.
State Water Commission of 1916.

STATE WATER COMMISSION OF CALIFORNIA,
SAN FRANCISCO, October 20, 1920.

State Water Commission of 1916,
632 Call Building,
San Francisco, California.

GENTLEMEN: Complying with your request of October 7, 1920, a plan is herein proposed for the adjustment of future diversions of the Spring Valley Water Company on Alameda Creek to meet the conditions of the agreement of September, 1916, between this company and the Alameda Water District. Concerning this the agreement reads:

WHEREAS, The parties have been unable to agree upon the terms of such settlement by reason of the lack of physical data necessary for a fair consideration of all the plans of settlement suggested, or for an intelligent and fair solution of all of the questions involved, and it is desired to obtain such data under the direction of some

competent and disinterested board, and when it is obtained to have a decision as to what is a fair and reasonable settlement, and the three appointed members of the State Water Commission have expressed their willingness to accept the direction of the work of gathering such data and to endeavor to decide as to such settlement; now, therefore

IT IS AGREED, for the period of three (3) years from the date hereof, unless the State Water Commission concludes that it has sufficient data at an earlier date, the State Water Commission shall direct, with full control and authority and without expense to the party of the first part, the work of obtaining such physical data as it may deem necessary for reaching an intelligent and fair determination of the conditions upon which the water company may, with due regard to the rights of the land owners within the water district, store water on Alameda Creek and its tributaries and increase the amount of its diversion therefrom. * * *

II.

Upon the completion of said three (3) year period, or earlier, in case it concludes it has sufficient data, the State Water Commission shall proceed in conference with the parties to fix and determine the terms and conditions, in accordance with the character of the particular season, upon which such storage and additional diversion may be made; provided, however, that such settlement shall not, without the consent of the parties hereto, prescribe a settlement by surface irrigation or other means of supplying water within the water district other than from the water-bearing gravel strata heretofore mentioned, the differences between the parties hereto being confined to the questions of the effect of the storage and additional diversion contemplated by the water company upon such waterbearing strata and resultant damage therefrom to lands within the water district underlain by such strata, and the respective rights in connection therewith of the parties hereto and of those for whom they are, respectively, acting, it being the object hereof to reach a settlement whereby, in the most economical and practical manner, it shall be made possible without further litigation to conserve and put to beneficial use the waters of Alameda Creek and its tributaries, which are now not put to use, and at the same time to prevent any damage being done thereby to those lands which are underlain by water-bearing strata supplied in whole or in part from Alameda Creek, or, if it is not possible to prevent such damage entirely, to compensate the owners of said lands to the extent to which such damage is not prevented, the making of such compensation by the water company, if it be provided for by such settlement, to be a condition of the exercise by the water company of any rights or privileges accorded to it by such settlement.

The physical data "necessary for a fair consideration of all the plans of settlement suggested, or for an intelligent and fair solution of all the questions involved" referred to in one of the opening paragraphs of the agreement, has been collected during the three years of investigation and has been presented to you in three annual reports on stream gagings, a report on irrigation and pumping draught from the underground waters of the Niles Cone and a summary report of June 1, 1920.

The principal facts developed by the investigation which are pertinent to a scheme of adjustment conforming to the provisions of section II of the agreement, are:

1. There is a large area of the Alameda County Water District underlaid by waterbearing strata which have their principal source of replenishment from waters percolating from Alameda Creek. (Pages 143 to 148, summary report of June 1, 1920.)

2. There is percolation into the same area from Dry Creek, Laguna Creek, and adjacent hill drainage which probably joins with the waters percolating from Alameda Creek in these strata. It is estimated that these combined minor sources of supply furnish about 5 per cent of that from Alameda Creek. (Pages 148 to 150, summary report of June 1, 1920.)

3. The elevation of the water in the wells of this area fluctuate in a yearly cycle rising in the winter and spring and dropping in the summer and fall in sympathy

with the general cycle of flow in Alameda Creek. There is also a fluctuation in the general levels from year to year. (See volume of well hydrographs accompanying summary report of June 1, 1920.)

4. There is a draught on the waters of these strata by pumping from wells for irrigation, domestic water supply and industrial purposes which totaled about 6100 acre feet in 1900, increasing to 8800 acre feet in 1909, to 15,900 acre feet in 1916, and to 18,000 acre feet in 1919. (Page 163 of summary report of June, 1920.)

5. There are other means of escape of waters from these strata of minor importance, the volume so escaping in 1916 being estimated at 2200 acre feet, and in 1919, 700 acre feet. The principal escapes are through evaporation from the ground surface and the transpiration from plant growth along the bay shore where the water plane stands comparatively near the ground surface. (Pages 164 to 173, summary report of June 1, 1920.)

6. The total annual replenishment to the waters of these strata in years of a fair creek flow such as 1915 and 1916 is barely equal to the present annual draught on these waters. (Pages 176 and 163 of summary report of June 1, 1920.)

Therefore, since—

1. There are draughts on these underground strata in very substantial quantities which are without the control of the water company;

2. There are additional sources of supply to these strata other than percolating water from Alameda Creek which sources are without the control of the water company;

The only measure of "the effect of the storage and additional diversion contemplated by the water company upon such waterbearing strata" for which the water company could logically be held responsible is the *quantity of percolation* withheld from these strata by reason of such storage and additional diversion.

The quantity of percolation so withheld can be determined but in one way. It is the difference between the percolation which actually occurs in any season and that which would have occurred had there been no storage or additional diversion by the water company. The difference may be arrived at through an expression of the relation between the volume of flow in Alameda Creek at the head of Niles Cone and the amount of water percolating to the waterbearing strata underlying the Alameda County Water District. With such an expression, a record of the actual flow in the creek and the amount of storage and additional diversion occurring in any season, the quantity percolating from the actual flow and the quantity which would have percolated from a flow which would have occurred had there been no storage or additional diversion may be arrived at for each particular season. The difference or the *quantity of percolation* withheld from the waterbearing strata underlying the district by reason of any storage or additional diversion on the part of the company is then determined "in accordance with the character of the particular season upon which such storage and additional diversion may be made." It is therefore a measure of the responsibility of the water company which meets the specifications of the agreement between the parties for fixing the terms and conditions upon which such storage and additional diversion may be made.

The expression of the relation between the volume of flow in Alameda Creek at the head of Niles Cone and the amount of water percolating to the waterbearing strata underlying the Alameda County Water District necessary to evaluate this measure of the responsibility of the

water company has been deduced from the data obtained by the Commission in their three years of investigation. As stated in the introductory chapter of the summary report of June 1, 1920, the principal effort of the field investigation was directed to the measurement of the percolation from the creek channel with view to determining the manner of variation of its rate. As there described, every possible effort was put forth to accomplish this purpose. The immense volume of data gathered was subjected to a severe analysis resulting in the establishment of a mathematical expression of the desired relationship on page 120 of the summary report.

This mathematical expression or formula is a concise statement of the conclusions from the three seasons gagings. It is of the type known as an "emperical formula" in distinction from a "theoretical formula." An emperical formula is constructed on a skeleton approximating a correct theoretical statement of relationship and has one or more terms whose values are derived from the direct measurement of the quantity for which the formula is to be solved. Such a formula then is only a convenient means of interpolating and exterpolating on the data from which these terms are evaluated. The accuracy of an emperical formula is the accuracy of the data from which it is constructed. Nearly all the useful formulas of the science of hydraulics are of the emperical class, foremost among which are the Kutter and Chezy formulas for flow in open channels, the Francis and other weir formulas and the various formulas for determining the friction of running water in pipes. The extreme complication of the detail laws of hydraulics practically prohibit an absolutely correct theoretical statement of them by formulas. The practical procedure in science is therefore to construct "emperical formulas" wherein errors in the conception of the theoretical skeletons of the formulas are absorbed in the terms derived from actual observations.

In the instance at hand the skeleton of the formula was constructed to take into account all the factors affecting percolation from the creek channel known to the science of hydraulics. By analogy to the hydraulics of filtration through sands and filter beds, the laws of which have been well established by engineering study and experiment in connection with the supply of drinking water to large cities, the quantity of percolation varies with:

1. The effective head acting or the difference in water levels between the influent and effluent.
2. The area of the beds through which percolation is occurring.
3. The depth of the beds through which the percolation is occurring.
4. The size of the particles through which the percolation is occurring.
5. The viscosity of the water percolating.

All attempts to apply these units to percolation from the creek channel failed since the level of the effluent and the depth of the beds are indeterminate quantities. However, after much study, physical units were discovered which incorporate all the variables listed above and in which the law of percolation could be approximately stated. They are:

1. Mean daily flow in the channel.
2. Maximum mean daily rate of percolation.
3. Per cent of maximum mean daily rate of percolation occurring.

4. Change in per cent of maximum mean daily rate of percolation from one day to the next.
5. Coefficient of viscosity of the water.

The size of the particles through which the percolation occurs is omitted since in a formula applying to a given channel it would appear as a constant.

The mean daily flow in the channel incorporates a portion of the effective head and the area of the bed through which the filtration is occurring. That portion of the effective head acting which lies between the water surface in the creek and the bottom of the channel as well as the area of wet stream bed vary with the mean daily flow in the channel. Thus in replacing these two elements by the mean daily flow no variable is lost to the formula. The other portion of the effective head which lies between the bottom of the channel and the level of the effluent, and the depth of the beds through which the percolation is occurring determine the "back pressure" or resistance to percolation at the bottom of the channel. This "back pressure" is also a function of the rates of percolation which have occurred for a time prior to the day under consideration for it distinctly depends upon the amount of water which has percolated just previously and which stands in the way to hinder additional percolation. The rate of percolation which occurs when there is no "back pressure" is here called the maximum rate of percolation. The effect of the "back pressure" in reducing this rate is here expressed in per cent of the maximum rate. It was found that the increase or decrease in the per cent of the maximum rate, occurring from one day to the next, follows a definite law and depends upon the actual rate of percolation occurring on that day. The replacement of that portion of the effective head which lies between the bottom of the channel and the level of the effluent and the depth of the beds through which percolation is occurring by these terms which equally well define this "back pressure", permit the construction of a formula expressing the relation between the flow in the channel and the rate of percolation without any indeterminate quantities and which incorporates all the variables known to science.

The viscosity of the water enters this expression in the same manner that it does in the formula for the rate of percolation through filter beds. However, in this instance the temperature of the water had to be approximated by using the air temperature at San Jose, about twenty miles distant. A series of observations indicated that in general, the mean daily air temperature at San Jose and the mean daily temperature of the water in Alameda Creek were about the same.

The expression deduced is:

$$P = \frac{.013\ M\ (C+K)}{V}$$

where

P=mean daily percolation in second-feet.

V=Coefficient of viscosity of water for mean daily air temperature at the United States Weather Bureau Station at San Jose.

M=Maximum mean daily percolation in second-feet for the mean daily flow occurring at a temperature of 50 degrees Fahrenheit or the mean daily rate of percolation which would occur with the temperature 50 degrees Fahrenheit and no "back pressure" acting. (Obtained from diagram entered for mean daily flow.)

C=Per cent of maximum mean daily percolation occurring on the day before the one under consideration.

K=Change in per cent of maximum mean daily percolation from day before to one under consideration. (Obtained from diagram entered for value of P for day before.)

The formula is accompanied by two diagrams to be used with it. One diagram (Nos. 10*a* and 10*b*) shows the relation between the flow in the channel and the maximum rate of percolation, temperature 50 degrees Fahrenheit, and was developed from field observations. This represents the mean daily rate of percolation for the first day of floods in a relatively dry channel when there is no "back pressure" prom past contributions to the ground water by percolation to limit the present rate of percolation. A second diagram (No. 11) showing the relation between the rate of percolation on one day and the change in the per cent of maximum percolation occurring between that day and the next was developed from the field data. The diagram is entered with the rate of percolation for any day to obtain the change in the per cent of the maximum percolation resulting from the contribution of that day's percolation to the "back pressure." This change in the per cent of maximum percolation is added or subtracted to the per cent occurring on that day to get the per cent which will occur during the next 24 hours.

This formula with its two diagrams developed from actual observations is a convenient means for determining the rates of percolation for conditions other than those for which actual observations were recorded. The variety of circumstances surrounding percolation were found to be so nearly infinite in number that it would require a period of time indefinitely long to actually measure the percolation under all the conditions that might occur. Therefore some such medium as this formula is necessary to discuss percolation for any other period than that during which the measurements were taken.

In addition to this, in reviewing the gagings during the many analyses required in the development of this formula, it was found that all portions of the work were not of equal accuracy and that very erroneous conclusions might be drawn from the consideration of parts of the work alone. Therefore, only through a comprehensive study such as was necessary to evolve this formula could the correct relation be deduced between the quantities involved and the various inaccuracies of individual portions of the work be eliminated.

A study of the measurements shows that the relation between gage-height and discharge at the gaging stations held constant for but very short periods of time. This meant that the station rating curves from which the mean daily discharges were computed were continually shifting. Therefore to get daily discharges sufficiently correct for the discussion of percolation, required practically continuous gaging at both current meter stations during flood periods. Inasmuch as this could not be accomplished due to the necessity of the field crew resting at intervals, there were periods in which the mean daily discharges are in error due to the lack of gagings.

Also much of the stream gaging of these investigations was performed under very adverse field conditions. The high flows were of short

duration with rapid changes in gage-height and generally occurred while the storms were still in progress. This made it necessary to continue gaging through day and night regardless of weather conditions. Many of the gagings were made during driving storms and at night. Quantities of drift in the flood flows added greatly to the difficulties. In spite of these trying circumstances, an analysis of the relative accuracy of the work shows that a high degree of perfection was obtained at all times. However, the discussion of rates of percolation on Alameda Creek requires an accuracy considerably greater than that usually attained in first-class current meter work so that the varied circumstances of the field work materially affect the value of portions of the work for this purpose.

Furthermore, the reduction of the field measurements to obtain the mean daily rates of percolation was a most intricate task. The flow in the stretch of channel 6¾ miles long between the upper and lower gagings stations was never uniform or steady. The discharges at the two ends were continually fluctuating relative to each other with water entering or leaving storage in the basin between. The storage capacity of this stretch of channel to the 10,000 second-feet flow line is 1725 acre-feet, which requires a flow of 870 second-feet for 24 hours to fill it. It was found that erroneous conceptions of rates of percolation might easily be obtained from gagings or series of gagings unless these elements of relative fluctuating flow at the two gaging stations and channel storage be taken into account. To properly make these reductions in obtaining the mean daily rates of percolation required sequence to the observations. Work of a single day, regardless of its accuracy was of little value for this purpose.

For these reasons, it was necessary to use interpretative judgment in deducing the manner of variation of percolation from the large mass of data collected. A careful examination of the field data which is well supported by current meter gagings shows that 78 per cent of it shows a very consistent relation between the rates of percolation measured on successive days. The remaining 22 per cent of the data which was obtained under very adverse conditions showed no consistent relation in the variation of mean daily percolation. It being inconsistent and disagreeing with the 78 per cent of the data taken under more favorable circumstances, was discarded in the final analysis of the rates of percolation.

The data used covers 108 days of intensive field work during which time the flow in the creek varied from low water conditions to the maximum discharge which can be carried within the banks of the stream without overflow. The data includes two "peaks" with a flow of 10,000 second feet, one with 5000 second feet and one with about 3000 second feet discharges. Flows greater than 10,000 second feet overtop the banks of the stream between the gaging stations. The overflow spreads out over the adjacent country in a manner which prohibits its measurement. All measurements of percolation must therefore be confined to flows of less than 10,000 second feet. Rates of percolation for greater flows can only be obtained by deduction. The data used in the final analysis therefore covers the entire range of flows for which it is possible to measure percolation.

In addition to the discard of a portion of the data in the final analysis, interpretative judgment was also used in the construction of the formula and diagrams from the remaining data. Apparently much of the data had a higher degree of relative accuracy than of absolute accuracy. This was taken into account in the deductions so that the formula does not yield results in exact agreement with the average data from which it was constructed. The percolation computed by the formula for the 108 days of intensive field measurements used in its development is 17.5 per cent greater than that actually measured over the same period. This 17.5 per cent of percolation corresponds to 1.1 per cent of the flow in the channel for the same period. The interpretative judgment introduced in the deduction of the formula therefore corresponds to about 0.5 per cent error at each of the gaging stations. This is entirely within the limits of probable error of the field work, and hence the interpretation is warranted to gain logic and consistency in the results.

The formula with its two diagrams is therefore presented as being the most nearly correct statement of percolation from the creek channel and its manner of variation which can be arrived at. Your attention is called, however, to the fact that this discussion is limited to the percolation from the creek channel between the two gaging stations. On page 129 of the summary report of June 1, 1920, it is pointed out that there is undoubtedly some percolation from the creek channel below the lower gaging station. The quantity is estimated at about 10 per cent of that occurring between the two gaging stations. Accepting this estimate, the percolation computed by the formula should be increased 10 per cent to obtain the total percolation from the creek channel to the waterbearing strata underlying the district.

Then, using this formula with its two diagrams to evaluate the quantity of percolation, it is proposed as "the condition upon which storage and additional diversion may be made" that the company release stored water in sufficient amounts and at such times during any season that the percolation from the released water to the waterbearing strata underlying the district be equal in quantity to that withheld from percolation during that same season by reason of the storage and additional diversions made during that season by the water company.

Respectfully submitted,

PAUL BAILEY,
Engineer.

PLATE XVIII.

Headgate of Peoples Ditch on Kings River at which diversions are regulated by water master under supervision of State Water Commission.

APPENDIX G.

WORK OF STATE WATER COMMISSION ON KINGS RIVER.

Kings River, with a drainage area of 1742 square miles, and an average annual discharge of 2,000,000 acre feet, is the largest stream entering the San Joaquin Valley. The watershed extends to the summit of the Sierra Nevada, more than half being high mountainous country. The snowfall melts but slowly, and consequently, the river reaches its highest stage in most years between the middle of May and first of June. A total of more than 40 ditches with a combined capacity of 10,000 second feet divert from the river and irrigate 625,000 acres. The distance from the highest diversion to the lowest diversion on the North Fork measured along the river is 70 miles, and to the lowest diversion on the South Fork is 65 miles. The canal systems cover an area of approximately 1300 square miles.

The Kings River area comprises in round numbers about 2,000,000 acres. At various times during the past twenty years, attempts have been made to perfect an organization of the canal interests and construct a dam to impound water in the Pine Flat Reservoir. With the enactment of the California Irrigation Act, this organization resulted in the Kings River Conservation District Executive Committee. On account of the extent and diversity of the interests involved, the organization of a storage project presented more complications possibly than on any other stream in the state.

The first task before the committee was an agreement with settlement of existing rights, as the storage scheme contemplated that these rights should remain intact. Most of the low and medium stage water rights had been defined by court decrees, judgments and agreements, but no complete data were available showing to what extent diversion and use had conformed with the claimed rights. At a meeting of the committee held in Fresno in October, 1917, a resolution was adopted which in part is as follows, to wit:

> WHEREAS, in our judgment, it will be a great aid to such cooperation and settlement of rights, if an accurate record be kept from year to year of all water diverted from Kings River and such other data as may be necessary to fix a basis for the just determination of the rights of the various canal interests and communities.

This resolution was sent to the State Engineer with the request that he furnish the engineer and the necessary assistance. This office, however, was unable to undertake the task on account of lack of funds. After considerable correspondence between the State Engineer, State

Water Commission, United States Geological Survey, and the committee, the President of the Water Commission, at a meeting in Fresno, made a statement in substance as follows: That through the cooperation of the United States Geological Survey, the Commission, at its own expense, would furnish engineers to make measurements and keep records of water flowing in Kings River and all canals diverting therefrom, and also of the amount of water flowing to Tulare Lake and the San Joaquin River. Where automatic water stage recorders are established they would keep gage height records without expense to the canal company but upon each canal requiring staff gage readings, financial aid should be furnished by the canal company to take such reading. All measurements, readings and records were to be made under the direction of the State Water Commission by its engineer.

A committee of five was appointed to prepare an agreement among the canal companies containing the following conditions and provisions:

First—Giving permission by each canal company to have its canals measured by the engineer of the Water Commission and a record kept of all diversions.

Second—Each canal company agrees to prepare a place of measurement as directed by the engineer.

Third—Canals not provided with automatic gages agree to pay expense of reading staff gages.

Fourth—All canal companies agree to stipulate not to make use of the results of such measurements in any suit or matter now pending between any of said companies.

Fifth—Each canal company agrees to furnish local transportation.

The engineer of the State Water Commission arrived in Fresno on December 27, 1917, and immediately entered upon his work. The first step was to become familiar with the location and character of the various canal intakes. In this he was greatly aided by the assistance of Mr. I. Teilman, Manager Fresno Canal and Land Corporation, Mr. M. W. Enderlein, Engineer South Side Canal Companies, Mr. Charles Rice, Superintendent Alta Irrigation District, and others. Acknowledgment is made of information received and courtesies extended by these officials and the many employes of the various canal and irrigation companies. A number of canals were already equipped with gaging stations and most of the others immediately built structures in accordance with the directions of the engineer.

After a reconnaissance covering about one week, it was found desirable to make some changes in the plan of operation as outlined in the agreement among the canal companies. Instead of depending on local transportation, a car was purchased and headquarters established in

Fresno. The Water Commission secured the use of twenty-one automatic water stage recorders for use on the work from the United States Department of Agriculture. This was a sufficient number to place one on each canal to be measured and not already equipped, thereby eliminating the need of observers for staff gages. At the end of February water stage recorders were in operation on four canals, and at the end of March on fourteen. With the coming of warm weather, the number of canals diverting and area irrigated increased rapidly. It soon became evident that it was too big a job for one man to carry out the program of visiting all canals two or three times each week besides giving some attention to waste and return waters. Accordingly, early in April, an assistant was employed with headquarters in Hanford, who took over some of the canals until July, or during the principal irrigating season.

In addition to keeping a continuous record of gage heights, all canals were measured with current meters throughout the irrigating season as frequently as was deemed necessary to determine a rating curve or curves. As the character and condition of the canals vary within wide limits, some required many more measurements than others. Those diverting near the foothills have clean channels, permanent cross-sections, and relatively high velocities. As a result the ratings show very little change from year to year. On the lower river, canal gradients are very flat in most cases less than one foot per mile. Raising or lowering a checkgate two or three miles down the ditch may have a noticeable effect on the rate of flow at the intake. At high stages of the river large quantities of sand are deposited in the upper reaches of the canals. In the late spring and early summer months, aquatic plants and tules grow abundantly, greatly decreasing the rate of flow. All these are factors in changing the rating. In one instance, no less than seven rating curves were used in a single irrigating season.

Daily diversion records were kept during the year 1918, on the following canals: Alta, Gould, Fresno, Consolidated, Lake Lands, Peoples, Last Chance, Emigrant, Lemoore, Grant, "A," Island, Liberty, Turner-Riverdale, Little Mill Race, Big Mill Race, Reed, Crescent, Stinson, Beta Main, Jap, and Carmichael Slough. No satisfactory results were obtained on Beta Inside, Empire Canals Nos. 1 and 2, Blakeley and Tulare Lake Canals. The conditions of operation on these canals were such that it was impossible to make current meter measurements as the velocities over most of the cross-section were, a large part of the time, almost imperceptible. Records were also kept of the Kings River flow into Lake Tulare below Empire Weir No. 2 and into the San Joaquin River at Elkhorn Grade near Burrel. (See Diagram 12 for location of canals.)

The engineer as "a competent and responsible appointee of the State Water Commission, acting under the direction and supervision of said Commission," was also assigned the duty of operating the headgate of the Lake Lands Canal in accordance with a stipulation entered into under date of March 16, 1918, under the provisions of the War Emergency Water Service Act. This canal was completed in 1903 to a capacity of about 800 second feet, but was enjoined from operating by lower riparian owners. Late in 1917 it was proposed under the authority of the above act, and upon the initiative of the State Council of Defense, that Lake Lands Canal and Irrigation Company, as an emergency war measure, be permitted to divert water from Kings River subject to certain limitations. Negotiations with this end in view resulted in a stipulation, assented to by the holders of the injunction, setting the injunction aside during the period of the war and for a period of six months thereafter. Under the terms of this stipulation, the canal company was permitted to divert sufficient water to furnish one irrigation for 25,000 acres of land. For the purpose of the agreement, the quantity of water necessary was fixed at 37,500 acre feet. It was further stipulated that no water should be diverted until twenty-four hours after the official gage at Piedra indicated that there were 8000 second feet or more passing that point, and that diversion should cease ten hours after there was less than 8000 second feet. By this stipulation Lake Lands Canal received water for a period of about five weeks, but owing to the foulness of the canal and the failure to remove two dams before the water came, it was impossible to divert a greater flow than 78 second feet. In all, about 1700 acre feet were diverted.

In November, largely through the efforts of Mr. Curtis H. Lindley, of the State Council of Defense, surplus water from the South Side Canal Companies was diverted into Lake Lands Canal. It was distinctly understood that both diversion and distribution of this water should be under the direction of the representative of the State Water Commission, and that it should be used only to irrigate growing wheat. Under this arrangement, the canal was in operation from November 29, 1918, to February 21, 1919. The total diversion amounted to 8585 acre-feet. It was conveyed nearly 50 miles. About 40 per cent of this reached the wheat lands, 60 per cent being lost by seepage and evaporation from the canals.

Beginning with the year 1919, the records of canal diversions and river flow were kept in the same manner as in the year 1918, until July when the duty of water master was added to the other duties of the engineer. Efforts to have the waters of Kings River distributed by

state authority culminated in a meeting on July 28th of all canal interests entitled to divert the low flow. It was verbally agreed that the engineer of the State Water Commission should distribute the water during the remainder of the year in accordance with the following schedule:

Quantities in Cubic Feet per Second.

Kings River at Piedra	Fresno Canal	Gould Canal	Kings County Canals	Laguna and Murphy Canals
449	100	00	819	30
1,500	1,000	151	819	30
1,600	1,000	201	869	30
1,700	1,000	201	469	30
1,800	1,000	251	519	30
1,900	1,000	301	569	30

Fresno Canal and Land Corporation during August and September takes the first 249 second feet. Kings County Canals take the next 200 second feet, and Fresno Canal and Land Corporation takes all over 449 second feet.

Under the old method, each canal superintendent or engineer was responsible to the water users under his canal to see that their full supply was being diverted. Such a method, while satisfactory as long as the flow of the river exceeded the combined capacity of all the canals, developed endless disputes and friction during low water stages. It will be seen from the above tabulation that the rights are based on the flow at Piedra, the United States Geological Survey gaging station above the highest irrigation diversion. The gage reading at Piedra is made and reported by the Weather Bureau at seven o'clock each morning, and diversions are made in accordance therewith until the next morning. During the spring months there is a large diurnal variation in the flow caused by the changes in the rate of snow melting due to difference of temperature between day and night. The difference between the daily maximum and minimum flow, in extreme cases, amounts to 50 per cent of the minimum for medium stages of the river. The maximum occurs in the morning and the minimum in the late afternoon or evening. As the official gage reading almost coincides with the maximum stage when the river is affected by snow melting, the daily mean discharge is considerably overestimated. This condition is the cause of many of the difficulties encountered.

Mr. Teilman, Manager of Fresno Canal and Land Corporation, presented a proposed schedule for distribution of water from Kings River for all stages from 2000 to 6500 second feet, and largely at his suggestion a meeting was called for August 25th of all canal interests entitled

to receive water under the 6500 second foot stage. The meeting was well attended, but after several hours discussion ended in a deadlock.

This, however, did not close the matter. Sentiment was strongly in favor of adopting a schedule of distribution. At the suggestion of the engineer of the State Water Commission another meeting was held on October 18th at which he stated the purpose of the meeting, and presided. Nearly all canal interests having defined rights were represented. The meeting unanimously passed resolutions declaring itself in favor of agreeing on and adopting a schedule of distribution and placing its operation in the hands of a water master acting under the authority and supervision of the State Water Commission. It was also decided that a working committee be selected consisting of one member from each company. The members named immediately met as a committee and elected W. P. Boone and C. L. Kaupke Chairman and Secretary, respectively. Plans of procedure were discussed which led to the decision that each canal company present a tentative schedule of its rights to serve as a basis for discussion. The committee went on record as desiring and requesting that the engineer of the Commission be employed for the year 1920 to carry on and continue his work and water measurements on Kings River.

Beginning with the year 1920, the scope of the work was considerably enlarged. Measurements were made and records kept of diversions by the canals of the lower river where no satisfactory results had been obtained heretofore. To furnish data especially desired by the schedule committee, studies were made of diversions in Centerville Bottoms and of seepage losses and return waters from the river channel.

About twenty miles east of Fresno, Kings River debouches from the foot hills of the Sierra Nevada Mountains and enters Centerville Bottoms. These bottoms, which have a length of eight miles and an average width of three miles, are depressed below the general surface of the San Joaquin Valley plain about ten feet at the upper end and sixty feet at the lower end. The river flows through the area in several channels and the existence of numerous old channels and sloughs is ample evidence that the river has changed its course from time to time. The result has been the cutting of the land into many small irregular pieces.

The area is largely riparian and irrigated by no less than twenty small ditches and pumps. Because of the fact that the ditches are riparian and among the oldest on the river, and that much of the water diverted drains back into the river, they have been comparatively free from legal attacks by the larger canal interests for the purpose of defining their rights or to limit the quantity diverted.

The consensus of opinion among canal officials and irrigation engineers has been that the actual quantity of water used in the bottoms was more than offset by seepage into the river from adjacent higher lands. However, in connection with the work of arriving at a diversion schedule, it was deemed advisable to secure more definite data on the subject. Consequently, beginning with July or immediately after the high water in the river, and continuing through August and September, the engineer has made measurements of all diversions. The combined capacity of all diversions, obtained by taking the sum of the maximum quantity measured in each ditch, was found to be 150 second feet.

In January an automatic water stage recorder was installed at Piedra and in July another at the site of the old Sanger gaging station below Centerville Bottoms and above the "Reedley Narrows" and a third one just below Peoples Weir.

While the measurements show some gain in the river flow between the Sanger station and Peoples Weir, it is not nearly so large as that obtained by measurements made several years ago. This is probably due, to some extent at least, to the lowering of the ground water table by pumping in areas adjacent to the river in the vicinity of Reedley.

This then, briefly, is the history of the work of the State Water Commission and the related activities on Kings River. While much remains to be done, more than a beginning has been made. At this time, near the end of the year 1920, the schedule committee has practically completed its work, and although the schedule has not been adopted, the various canal and irrigation interests are nearer to an agreement on their rights than ever before.

The most important feature of the work now is that of water master in supervising diversions from the river. It has been tried for more than a year and proven entirely satisfactory. The diversion schedule pre-supposes a water master and with its adoption his duties will be extended to cover nearly all diversions from the river.

TABLE 13.

Summary of Kings River Canal Diversions.

Name of canal	1918		*1919		*1920	
	Total diversion acre feet	Maximum diversion second feet	Total diversion acre feet	Maximum diversion second feet	Total diversion acre feet	Maximum diversion second feet
Alta	165,280	1,190	100,635	1,001	130,315	1,164
Gould	68,450	395	69,120	803	67,047	374
Fresno	234,935	1,044	247,245	1,049	219,885	1,070
Consolidated	219,200	1,417	166,950	1,503	212,256	1,517
Lake Lands	6,965	78	8,700	120		
Peoples	147,650	470	140,100	495	95,023	445
Last Chance	51,525	343	53,705	245	52,486	315
Lemoore	107,655	491	104,940	541	81,369	481
Emigrant	1,895	72	1,670	62		
Island	11,915	125	10,085	135		
Grant	32,550	223	39,080	358		
"A"	8,056	25	3,057	32		
Liberty	9,320	85	10,315	158		
Turner-Riverdale	18,120	205	21,795	167		
Little Mill Race	4,080	38	2,685	25		
Big Mill Race	10,730	98	12,040	114		
Reed	6,405	46	7,500	64		
Crescent	7,305	149	9,795	169		
Stinson	10,155	197	10,575	184		
Beta Main	7,560	98	5,910	104		
Jap	1,495	31	821	17		
Carmichael Slough	7,825	177				
Cuthbert-Burrel			3,610	93		

NOTE: Tabulations for 1920, on seven canals, are for January to June inclusive.

*Three day average.

APPENDIX H.

PROGRESS REPORT ON SAN JOAQUIN HYDROGRAPHIC SURVEY.

Actual work on the survey was begun June 11, 1920. The progress to date has consisted chiefly of a study of field conditions to be met and securing the cooperation of the various interests using San Joaquin River waters. Current meter gagings have been taken on the various irrigation canals and return water measurements made on the main San Joaquin River and two of its tributaries. The installation of water stage recorders on the gravity canals was completed September 4th. The various companies and irrigation districts diverting from the river have all indicated their willingness to furnish what data has been obtained, and have cooperated fully in the establishment of measuring stations.

Scope of Survey.

The survey will deal principally with the main San Joaquin River, including its mountain drainage area and the San Joaquin Valley portion at the lower end of the valley, together with the three tributaries, Fresno, Chowchilla and Merced Rivers. In addition to the above, measurements will be taken on the Tuolumne and Stanislaus Rivers in the study of return water from irrigation.

The investigation will consist of three phases, as follows:

(1) The measurement and study of flow in the main San Joaquin River and the above named tributaries.

(2) The measurement and study of diversions from the main San Joaquin River and its tributaries; the present use of water for irrigation; and the effect on irrigation of the release of stored water from power reservoirs.

(3) The measurement and study of return water from irrigation.

Stream Flow Measurements.

The work under Phase (1) will consist largely of the compilation and study of stream flow records made available through cooperation with the United States Geological Survey, the Southern California Edison Company, and the San Joaquin Light and Power Corporation. In addition, stream flow measurements will be made at existing United States Geological Survey gaging stations on the main San Joaquin River and at proposed gaging stations on the Fresno, Chowchilla and Merced Rivers.

At present gages are being maintained on the San Joaquin drainage area covered by this survey, as follows:

Stream	Location of station	Type of gage	Observed by
South Fork San Joaquin	Florence Lake	Water stage recorder	Southern California Edison Company
San Joaquin	Above junction Big Creek	Not known	Southern California Edison Company
San Joaquin	Above Kerckhoff Dam	Water stage recorder	San Joaquin Light and Power Corp'n.
San Joaquin	Near Friant	Gurley printing	United States Geological Survey
San Joaquin	Near Newman	Staff	United States Geological Survey
Bear Creek	Five miles above junction with South Fork of San Joaquin	Staff	Southern California Edison Company
Mono Creek	Vermillion Valley	Staff	Southern California Edison Company
Huntington Lake Drainage Area	Huntington Lake	Water stage recorder	Southern California Edison Company
Pitman Creek	Near confluence with Big Creek	Hook gage at weir	Southern California Edison Company
Stevenson Creek	Near Shaver Lake	Water stage recorder	Southern California Edison Company
Stevenson Creek	At S.S.&E.R.R. crossing	Water stage recorder	Southern California Edison Company
North Fork Creek	Crane Valley Reservoir	Not known	San Joaquin Light and Power Corp'n.
South Fork Creek	Near North Fork	Water stage recorder	San Joaquin Light and Power Corp'n.
Fresno River	Near Knowles	Staff	United States Geological Survey
Merced River	Exchequer	Staff	United States Geological Survey

In addition to the above, the Southern California Edison Company has undertaken a series of gagings on the Middle Fork of the San Joaquin River and its tributaries at critical points adjacent to proposed power projects within the drainage area.

It is also proposed as part of this investigation to establish additional gaging stations on the San Joaquin near Patterson, and on the Merced River near the Stevenson Ranch to aid in the study of return and waste water from irrigation. A permanent gaging station will be established on the Chowchilla River. An additional station is proposed for the Fresno River near Madera.

At present there are twelve major pumping plants and fourteen gravity canals and sloughs diverting water from the San Joaquin River for irrigation. The pumping plants are located on the lower reaches of the river between Patterson and Brentwood and irrigate projects on the west side of the river. The Tranquillity pump is an exception, being located on Fresno Slough some ten miles southeast of Mendota. The Panoche Canal, a pumping project under construction diverting water from Fresno Slough just above Mendota Dam, has not been included in the above number of pumping plants. A temporary installation of a battery of four pumps, driven by a miscellaneous collection of steam and gasoline engines, has supplied water intermittently during the present season to a small acreage of Miller and Lux lands north of Mendota. There are also numerous small pumping plants along the river which have not been investigated. The diversion by gravity canals and sloughs lies between a point 15 miles southwest of Madera and a point 12 miles north of Dos Palos, the distance along the river between the upper (east side) and lower (west side) diversion points being some 65 miles.

Most of the gravity canals are at present equipped with staff gages, read daily, and records are available. For the purposes of the investigation, however, it has been deemed advisable to equip existing gaging stations, as well as new stations, with water stage recorders. Independently obtained observations will thus be depended upon.

A difficult problem is encountered in the determination of the total flow diverted and used for irrigation. While most of the canals admit readily the measurement of diversions, the measurement of return and waste water is made difficult by its intermingling with overflow from the river. This overflow water unites, and spreads over the plains, with water diverted by the east side canals, and is returned to the river in the same channels. Measurements to determine waste and return water from diversions will include more or less overflow water. The sloughs add to the above complications in that they may flow from or into the river or not at all, depending on the depth of inundation of the surrounding country and the stage of the river.

The canals diverting from the west side of the river present no unusual difficulties as to the measurement of diversions. There is some interchange of water between canals below gaging stations, but this can be controlled with the cooperation of the interests operating the canals. The determination of the amount of water used for irrigation is difficult. Return and waste water measurements must necessarily be made in the river and becomes involved with return and overflow water from the east side of the river.

The following is a summary of current meter measurements of diversion thus far made by the engineer in charge:

TABLE 14.

List of Current Meter Measurements on Canals Diverting from San Joaquin River.

Name of canal	Location	Date	Gage height feet		Discharge second feet
Gravelly Ford	Below headgate	6/19/20	(a)	3.1	152.7
Gravelly Ford	Below headgate	6/22/20	(a)	2.85	225.8
Gravelly Ford	Below headgate	6/22/20	(a)	2.85	222.0
Gravelly Ford	Below headgate	6/30/20	(a)	4.05	0.
Gravelly Ford	Below headgate	7/ 8/20	(a)	4.10	*5.0
Gravelly Ford Lateral	Bridge below head	6/19/20	(a)	4.6	46.4
Gravelly Ford Lateral	Bridge below head	6/22/20	(a)	4.5	45.8
Gravelly Ford Lateral	Bridge below head	6/22/20	(a)	4.5	45.6
Gravelly Ford Lateral	Flume over Aliso Canal	6/22/20	(a)	4.5	40.7
Gravelly Ford Lateral	Flume over Aliso Canal	6/30/20	(a)	5.2	21.7
Gravelly Ford Lateral	Flume over Aliso Canal	7/ 8/20	(a)	5.1	21.2
Gravelly Ford Lateral	Flume over Aliso Canal	7/21/20		0.	0.
Aliso	Bridge below head	6/22/20	(a)	4.1	305.8
Aliso	Bridge below head	6/22/20	(a)	4.1	311.4
Aliso	Bridge below head	6/30/20	(a)	5.9	136.9
Aliso	Bridge below head	7/ 8/20	(a)	6.0	129.6
Aliso	Bridge below head	7/21/20	(a)	7.0	48.6
Aliso	Bridge below head	7/31/20	(a)	7.5	22.6
Browns Slough	Below headgate	6/26/20	(b)	3.0	31.8
Browns Slough	Below headgate	7/21/20		0.	0.
Lone Willow Slough	Below headgate	6/26/20	(b)	7.1	286.2
Lone Willow Slough	Below headgate	6/26/20	(b)	7.1	291.4
Lone Willow Slough	Below headgate	7/21/20	(b)	5.3	141.2
Panoche Lateral	Below headgate	6/24/20	(a)	3.1	11.5
Panoche Lateral	Below headgate	8/ 7/20	(a)	3.5	7.4
Riverside	At Mendota Dam	6/24/20	(a)	3.2	23.3
Riverside	At Mendota Dam	6/30/20		0.	0.
Helm	Near Firebaugh	6/23/20	(c)	6.0	444.6
Helm	Near Firebaugh	6/30/20	(c)	5.8	437.7
Helm	Near Firebaugh	7/22/20	(c)	3.9	239.1
San Joaquin and Kings River Canal	Near Firebaugh	6/23/20	(c)	9.6	1,138.1
San Joaquin and Kings River Canal	Near Firebaugh	6/30/20	(c)	9.5	1,126.6
San Joaquin and Kings River Canal	Near Firebaugh	7/22/20	(c)	7.7	703.6
Outside Canal	Near Firebaugh	6/23/20	(c)	4.8	397.9
Outside Canal	Near Firebaugh	6/29/20	(c)	4.8	400.0
Outside Canal	Near Firebaugh	7/22/20	(c)	7.1	297.7
Temple Slough Canal	Bridge below head	6/24/20	(a)	1.5	571.2
Temple Slough Canal	Bridge below head	6/25/20	(a)	1.5	556.5
Temple Slough Canal	Bridge below head	6/29/20	(a)	2.5	353.2
Temple Slough Canal	Bridge below head	7/23/20	(a)	3.5	111.1
Clave Canal	Bridge below head	6/16/20	(a)	2.0	275.3
Clave Canal	Bridge below head	6/25/20	(a)	1.9	280.7
Clave Canal	Bridge below head	7/23/20	(a)	3.1	64.9
Clave Canal	Bridge below head	8/13/20	(a)	3.3	28.4
Madera Irrigation Company Canal	Below head	6/21/20	(c)	2.9	44.9

*Estimated.

(a) Distance to water surface from reference point.
(b) Mean depth of flume.
(c) Staff gage.

Return Water.

The work of this survey under Phase (3) will consist of securing return water measurements on the San Joaquin and its tributaries. The following is a summary of return water measurements already made:

Date	Stream	Location	Discharge second feet
7/12/20	San Joaquin River	Below Mendota Dam	(a) 13.5
7/29/20	Tuolumne River	Below Modesto Greyson Bridge	304.1
7/30/20	Merced River	Below confluence with San Joaquin	48.4
8/13/20	San Joaquin River	Pick Anderson Slough	(b) 28.4

(a) Leakage through Mendota Dam.
(b) Measured in Clave Canal.

Summary.

The area covered by the survey comprises the main drainage area of the San Joaquin River.

A certain amount of dependence will have to be placed on the various interests using San Joaquin River waters in furnishing available records for the determinations of the problems within the scope of the investigation.

The principal amount of field work will be encountered within the valley portion of the drainage area consisting of obtaining accurate records of canal diversions and the portion of these diversions used for irrigation. To date, all effort along these lines has been devoted to establishing gaging stations preparatory to obtaining a full season's record next year.

In general, there is a lavish use of water for the irrigation of pasture lands and native wild hay. The principal cultivated crop is alfalfa. A variety of other crops is grown, all requiring irrigation for successful production.

The necessity for water in the development of the resources of the San Joaquin Valley demands that the work undertaken by this survey be continued and studies made which may ultimately be needed to accomplish a just adjudication of existing water rights based upon beneficial use.

APPENDIX I.

REPORT TO THE STATE WATER COMMISSION ON THE PROGRESS OF THE COOPERATIVE SURFACE WATER INVESTIGATIONS IN CALIFORNIA BY THE WATER RESOURCES BRANCH OF THE U. S. GEOLOGICAL SURVEY FOR 1919–1920.

The water resources investigation in the State of California, during the biennial period ending June 30, 1920, was maintained on nearly the same basis as for the preceding period. There were maintained a total of 178 gaging stations distributed throughout the state as follows: Sacramento drainage, 33; San Joaquin drainage, 49; South Pacific drainage, 49; North Pacific drainage, 12; and Great Basin, 35.

The following table gives the name of the stream and the location of each station maintained during this period:

Stream.	*Location.*
Alameda Creek*	Decoto
Alameda Creek*	Niles
American River*	Fairoaks
American River, Middle Fork	East Auburn
American River, North Fork	Colfax
American River, South Fork	Placerville
Arroyo Seco*	Pasadena
Arroyo Seco	Soledad
Baxter Creek	Lassen
Bear River	Colfax
Bear River	Van Trent
Bidwell Creek, at	Fort Bidwell
Bidwell Creek, near	Fort Bidwell
Big Dalton Creek*	Glendora
Black Canyon Creek	Mesa Grande
Boulder Creek	Julian
Box Canyon Creek	Fort Bidwell
Cache Creek	Yolo
Cajon Creek*	Keenbrook
Calaveras River	Jenny Lind
Carson River, East Fork	Markleeville
Carson River, West Fork	Woodfords
Cherry Creek*	Sequoia
City Creek*	Highlands
Clear Lake	Lakeport
Cooks Lake	Fort Bidwell
Cosumnes River	Michigan Bar
Cosumnes River, North Fork	El Dorado
Cowhead Lake	Fort Bidwell
Coyote River	Coyote
Coyote River	Edenvale
Coyote River	Madrone
Cuyamaca Water Company's flume at diverting dam	Lakeside
Cuyamaca Water Company's flume	Lakeside
Deep Creek	Adel
Deep Creek above Dismal Creek	Fort Bidwell
Deep Creek below Dismal Creek	Fort Bidwell
Deer Creek	Hot Springs
Devil Canyon Creek*	San Bernardino
Dismal Creek	Warner Lake
Eaton Creek*	Pasadena
Eel River	Scotia
Eleanor Creek*	Sequoia
Elsinore Lake	Elsinore
Falls Creek*	Sequoia
Feather River*	Oroville
Feather River, Middle Fork*	Sloat
Feather River, South Fork	Enterprise
Fifteen Mile Creek	Warner Lake
Fish Creek*	Duarte
Fresno Flume & Lumber Company's flume*	Shaver
Fresno River	Knowles
Gobernador Creek	Carpinteria
Goodyear Creek	Goodyear Bar
Haines Creek*	Tujunga
Horse Creek, North Fork	Fort Bidwell
Horse Creek, West Fork	Fort Bidwell
Indian Creek	Happy Camp
Janesville Creek	Lassen
Kaweah River	Three Rivers
Kaweah River, North Fork	Kaweah
Kaweah River, South Fork	Three Rivers
Keeno Creek	Fort Bidwell
Kern River*	Kernville
Kings River*	Sanger
Klamath River	Requa
Klamath River	Seiad Valley
Laguna Seca	Coyote
Little Santa Anita Creek*	Sierra Madre
Lone Pine Creek*	Keenbrook
Long Valley Creek	Doyle
Long Valley Creek	Scotts
Lytle Creek*	Rialto
Markleeville Creek	Markleeville

*Station is equipped with a water-stage recorder.

Stream.	*Location.*
Markleeville Creek	above Markleeville
McCloud River	Baird
Merced River	Exchequer
Merced River at Happy Isles*	Yosemite
Merced River at Pohono Bridge*	Yosemite
Merced River, South Fork	Wawona
Middle Eel River	Covelo
Mill Creek*	Craftonville
Mill Creek Power Canal*	Craftonville
Modesto Canal	La Grange
Mokelumne River	Clements
Mokelumne River, Middle Fork	West Point
Mokelumne River, North Fork*	West Point
Mokelumne River, South Fork	Railroad Flat
Mono Lake	Mono Lake
Monrovia Pipeline	Monrovia
Oakdale Canal	Knights Ferry
Oregon Creek	North San Juan
Owens Lake	Lone Pine
Owens River	Big Pine
Owens River	Lone Pine
Owens River	Round Valley
Pacoima Creek*	San Fernando
Palermo Land and Water Company's canal	Enterprise
Pine Creek	Alturas
Pine Creek	Round Valley
Pit River*	Henderson
Pit River	Ydalpom
Plunge Creek*	East Highlands
Putah Creek	Winters
Rock Creek	Fort Bidwell
Rock Creek	Goodyear Bar
Rock Creek	Round Valley
Rogers Creek*	Azusa
Sacramento River	Antler
Sacramento River	Castella
Sacramento River*	Red Bluff
Salton Sea	Salton
San Antonio Creek*	Claremont
San Diego River	Santee
San Dieguito River	Bernardo
San Dimas Creek*	San Dimas
San Gabriel River*	Azusa
San Jacinto River	Elsinore
San Joaquin River*	Friant
San Joaquin River	Newman
San Luis Rey River	Bonsall
San Luis Rey River*	Mesa Grande
San Pablo Creek	San Pablo
San Pablo Creek	near San Pablo
Santa Ana River*	Mentone
Santa Ana River*	Prado
Santa Anita Creek*	Sierra Madre
Santa Maria Creek*	Ramona
Santa Ynez River	Lompoc
Santa Ynez River*	Santa Barbara
Santa Ysabel Creek*	Mesa Grande
Santa Ysabel Creek*	Ramona
Sawpit Creek*	Monrovia
Schloss Creek	Lassen
Scott River	Callahan
Scott River, East Fork	Callahan
Shasta River	Montague
Smith River, Middle Fork	Crescent City
Smith River, North Fork	Crescent City
South San Joaquin Canal	Knights Ferry
Southern California Edison Company's Canal	Azusa
Southern California Edison Company's Canal	Mentone
Spanish Creek	Keddie
Stanislaus River*	Knights Ferry
Stanislaus River, North Fork	Avery
Stevenson Creek*	Shaver
Strawberry Creek*	Arrowhead Springs
Susan River	Susanville
Sweetwater River	Descanso
Temescal Creek	Elsinore
Tenaya Creek*	Yosemite
Trinity River	Hoopa
Trinity River	Lewiston
Tujunga Creek*	Sunland
Tulare Lake	Stratford
Tule River	Porterville
Tule River, South Fork	Porterville
Tunnel Diversion	Azusa
Tuolumne River*	Buck Meadows
Tuolumne River at La Grange Dam	La Grange
Tuolumne River above La Grange Dam*	La Grange
Tuolumne River at Hetch Hetchy dam-site*	Sequoia
Tuolumne River, at Middle Fork*	Buck Meadows
Tuolumne River, South Fork*	Buck Meadows
Tuolumne River, South Fork	Sequoia
Turlock Canal	La Grange
Twelve Mile Creek	Fort Bidwell
Twenty Mile Creek	Fort Bidwell
Utica Gold Mining Company's Canal	Avery
Waterman Canyon Creek*	Arrowhead Springs
West Walker River	Coleville
Yosemite Creek	Yosemite
Yosemite Power Company's Canal	La Grange
Yuba River	Smartsville
Yuba River, Middle Fork	North San Juan
Yuba River, North Fork	Goodyear Bar
Yuba River, North Fork of North Fork	Downieville

*Station is equipped with a water-stage recorder.

PLATE XIX.
GAGING STATIONS IN SANTA ANA DRAINAGE.

Lone Pine Creek near Keenbrook, California.

Waterman Canyon Creek near Arrowhead Springs,

A number of the above stations have been discontinued on account of lack of funds for the particular investigation, or because conditions were unfavorable for continuing the records. Fourteen of the above stations were established during the period on account of funds made available for that work. On June 30, 1920, 151 gaging stations were in operation. The above list does not contain a considerable number of stations maintained by private parties and furnished for publication in the Water-Supply Papers.

There has been a marked change in conditions affecting this work, especially during the past year. While there has been very little increase in the regular appropriations, the cost of every item of work is much greater than ever before. In order that even the present amount of work be continued, increased funds are necessary. In view of the strong demand for data regarding the water resources of the state, the river measurement work should be considerably extended, and more intensive work could well be undertaken on certain important streams.

Attention is called to the low discharge of all streams in the Sacramento and San Joaquin drainages during the past three or four years. In the Sacramento River basin, the run-off for the years 1917, 1918, 1919, and 1920 has been below the mean based on the entire length of records available. The principal station on Sacramento River is located a few miles above Red Bluff. The discharge at this station for 1917 was 71 per cent of the mean computed from the complete record beginning May, 1894; for 1918, 53 per cent; for 1919, 78 per cent; and from October, 1919, to July, 1920, 38 per cent. The run-off during May, June and July, 1920, was the lowest ever recorded for these months and a new minimum discharge of 3400 second-feet was established on July 25.

In the San Joaquin River basin, the run-off for 1917 was generally close to the normal, while 1918, 1919, and 1920 were deficient years. Kings River, which may be considered fairly representative of the important streams in this basin, has a stream flow record beginning October, 1895. The discharge of this stream, above all diversions, for 1918, was 72 per cent of the mean; for 1919, 63 per cent; and October, 1919, to June, 1920, 78 per cent. With the exception of May, the run-off for each month October, 1919, to June, 1920, was less than the normal, but in excess of the minimum recorded for these months.

This cycle of dry years in the Great Valley emphasizes the necessity for a rapid development of all feasible storage to meet urgent irrigation and power requirements. The present hydro-electric output during the low water season, combined with the full capacity of the steam plants, is not sufficient to meet the demands for electric power. The development of the extensive rice acreage in the Sacramento Valley and the shortage of water generally in the San Joaquin Valley, shows the necessity for increasing the supply of water available for irrigation.

It is important that a thorough study of storage possibilities throughout the state be undertaken without delay. River measurement stations, if not in operation, should be promptly established at all favorable reservoir sites, in order that the safe yield of the drainage may be determined in advance of construction.

As in previous years, the funds furnished by the State Water Commission have been expended chiefly in a study of the general water supply of the state. Several special investigations have been made at the request of the Commission. The most important was the study of the water supply in the Surprise Valley region and Honey Lake basin. In this area, 20 river measurement stations were maintained for the two-year period ending September 30, 1919.

Two years ago, at the request of San Bernardino, Riverside, and Orange counties, an intensive study was begun of the surface water supply throughout the Santa Ana basin. This investigation will include the collection of records of flow of Santa Ana River, at strategic points, and of all important tributaries entering the basin together with the diversions for power and irrigation. There are now in operation 14 gaging stations all equipped with water-stage recorders, which give a continuous record of stage of the streams. On account of the importance of this work, a permanent type of construction was selected. The water-stage recorders are housed in reinforced concrete structures built after standard plans developed for these special conditions. (See Plates XVI to XXI.) The United States Weather Bureau has established about 40 standard precipitation stations in this region, two of which are of the self-recording type. These records will be very useful in connection with studies of run-off conditions. The Survey expects soon to be able to detail a geologist, who will make a comprehensive study of the ground water in this basin.

PLATE XX.
GAGING STATIONS IN SANTA ANA DRAINAGE.

Strawberry Creek near Arrowhead Springs, California.

Cajon Creek near Keenbrook, California.

The maintenance of the Santa Ana stations is financed by special appropriations made by San Bernardino, Riverside, and Orange Counties. Substantial cooperation is also furnished by the Forest Service and Weather Bureau. The construction cost of a number of these stations was paid from a special appropriation of $5000 made by the last Legislature and disbursed by the State Water Commission.

This investigation is on the same basis as the one maintained in Los Angeles County during the past five years, where 17 gaging stations and 48 standard Weather Bureau precipitation stations are in operation.

In the administration of the work of the Water Resources Branch of the Geological Survey, the district office is maintained at 328 Custom House, San Francisco. A suboffice is retained at 602 Federal Building, Los Angeles, for the convenience of southern California and as a headquarters for work in the South Pacific drainage. Records of stream flow for all sections of the United States and data collected by other branches of the Survey may be consulted at either office.

The water resources investigation in California is under the general supervision of Mr. N. C. Grover, Chief Hydraulic Engineer, and Mr. John C. Hoyt, Hydraulic Engineer in charge of surface waters for the Geological Survey.

Respectfully submitted.

H. D. McGLASHAN,
District Engineer.

SAN FRANCISCO, CALIFORNIA, August 20, 1920.

APPENDIX J.

EMERGENCY WATER CONSERVATION CONFERENCE.

The winter of 1919-1920 arrived with a general expectancy of abundant rain and snowfall, following as it did two abnormally dry years. This fact, coupled with the favorable prices received for farm produce during 1919, added stimulus to crop planting programs for 1920. The unusually favorable price received for rice in 1919 was particularly effective in encouraging an extension of the rice acreage. Most of the rice produced in the state is raised in the Sacramento Valley where there are large areas suitable for its cultivation. The hardy qualities of the rice plant enable it to mature on clay and alkali land which is of small value for other purposes. The possibility of converting large areas of this poor land of the valley into excellent revenue producing acreages was most attractive. Thus, the year 1920 opened with plans for a great extension of the rice acreage over the previous season.

The large water requirements for growing rice as compared with other irrigated crops, and the proposed increase in acreage, made it apparent early in the season that there would be a demand for irrigation water in excess of that during any previous year, especially on the Sacramento River. Appreciating the seriousness of the situation, when December and January passed with extremely light rainfall and almost no snow in the mountains, the State Water Commission, on February 3 and 15, issued bulletins forecasting a shortage of irrigation water during the summer of 1920. Irrigators in the Sacramento Valley were warned to fully advise themselves of their rights to divert water and to consider the probability of their obtaining an adequate supply of water before proceeding with their plans for the season's plantings. These bulletins expressed the desire of the Commission to prevent as far as possible the loss of investment and crops which would result from a planting of a greater acreage than the available water supply could properly bring to maturity.

The month of February ended with the runoff in the Sacramento River at Red Bluff only 34 per cent of normal and the seriousness of the situation became more acute. Other departments whose functions were affected by the shortage of water in the river became interested.

Appreciating the value of cooperative effort, representatives of various state and federal offices met at the call of the State Railroad Commission, and after several conferences organized in the Emergency Water Conservation Conference. All the state and national bodies whose work had any relation to irrigation in the Sacramento Valley were thus brought together in a group composed of the State Engineer, the United States and State Departments of Agriculture, the Irrigation Investigations of the University of California, the Water Resources Branch of the United States Geological Survey, the United States Weather Bureau, the State Power Administration, the State Railroad Commission, and the State Water Commission.

The absence of any determination of the relative rights of claimants to divert water from the Sacramento River made a very difficult situation. The sum total of the proposed diversions for irrigation greatly exceeded the probable supply of the river during the summer. It was a difficult problem to determine who should give up planting to reduce the total water requirements to a figure commensurate with the probable supply in the river. Unless some acreage should be given up, it appeared that there might not only be large losses of crops from lack of water, but that costly and protracted litigation involving the conflicting claims of rival diverters might be precipitated and spread a cloud over the development of irrigation in the Sacremento Valley for years to come. The question as to who should reduce their contemplated rice plantings could not be answered without a determination of the relative rights to the use of the river water. This being a most intricate task on a stream as large as the Sacramento River and one which would require considerable time for making surveys and investigations and filing claims, no hope could be entertained for its accomplishment in time to be of use in the present season.

Representatives of the various districts and organizations of water users in the Sacramento Valley were therefore invited to meet with the conference and discuss plans to prevent the threatened litigation and to protect their mutual interests by concerted action for the conservation of the available water supply. After much discussion, lasting for several days, the Emergency Water Conservation Conference was invited to administer the diversion of water by a group of water users representing approximately 70 per cent of the irrigated area in the valley. These parties signed an agreement placing the distributing of water as between themselves in the hands of the Conference. They agreed to exercise their respective rights to the use of water during the season 1920, only as directed by the conference and to conform with and obey

the orders, rules and recommendations made by the conference for the conservation of water.

All possible data was gathered by the conference and estimates made of the area that could be irrigated, based on the probable supply in the river and the experience of past years. The acreage under control of the conference was divided into three classes: First, that for which there was a reasonable assurance of an adequate supply; second, that for which there would probably be a sufficient supply for early crops; and possibly for late crops; third, that for which the water supply would be precarious. The various public notices and discussions concurrent with the gathering and placing of this information before the public led to a general reconsideration of the planting programs in the valley which resulted in considerable voluntary reduction in the proposed acreage of rice. It is estimated that the proposed rice plantings were reduced some 50,000 acres because of the activities of the Conference in making the public fully acquainted with the seriousness of the crisis.

Several storms occurring about the middle of April materially relieved the conditions of drought in the southern part of the State and in the San Joaquin Valley. A fairly heavy snowfall on the watershed of the San Joaquin River gave prospects of a reasonable summer flow for irrigation in this Valley. Although these storms extended over the watershed of the American and Feather Rivers with considerable effect, they influenced the upper Sacramento River but little. Thus, the season progressed with a poor prospect of an adequate water supply in the great area of rice districts.

As the season advanced, all expectations of the shortage of supply in the Sacramento River were realized. The river reached the lowest stage in its history early in July at about the time of the peak of the irrigation demand, and continued to drop all through the irrigation season.

In spite of many difficulties, the conference instituted a program which was carried through the season successfully. Litigation over the conflicting claims to water was avoided; there were no clashes of interests; and, of paramount importance, all projects received ample water to mature their crops. The result was accomplished by increasing the duty of water. Careful use of the water and the avoidance of all waste were insisted upon. The conference adopted the rule that the headgate diversion of any project would arbitrarily be reduced for the waste or careless use of water, and placed engineers in the field under the water master to see that water was used with all due economy. With the projects under the jurisdiction of the conference in the lead, irri-

gation water was never handled so carefully in the Sacramento Valley as it was during the summer of 1920. The duty of water was greatly increased through the cooperation of all parties and waste of all kind was eliminated by the time the crisis of the season had arrived. The water used on each tract of land was limited to the actual requirements of the crops. All drainage water was picked up and used over again. Some, in fact, was used for the third time. By closely pressing all porsible measures for husbanding the supply, water was made available for all projects. There was no suffering from the lack of water wherever projects had ample facilities for diverting and distributing the necessary supply.

The season thus closed with the accomplished irrigation of the largest rice crop the valley has ever known, as well as a very large area of general crops. The degree of the crisis which was met is well expressed by the ratio of the total diverting capacity of all the projects to the flow in the river. At its low point, the flow in the river was just about one-third of the total capacity of all the pumping plants and diversions between Sacramento and Red Bluff. Had projects diverted to the full capacity of their systems and to the full extent of their claims to water rights, the river would have been dry early in the summer with no water for the lower projects.

Although a clash of interests was avoided during the past season, the necessity for an early determination of the underlying rights to divert water from the Sacramento River is the outstanding conclusion to be drawn from the season's activities. Without such a determination, there is absolutely no basis for a diversion of water among the various claimants in periods of shortage. Furthermore, the hazard facing irrigation development is great because of the uncertainty as to the amount of unappropriated water which may be left after prior and vested rights are satisfied.

APPENDIX K.

COLUSA BASIN.

Colusa Basin is a strip of land about fifty miles in length occupying a natural depression paralleling the Sacramento River on the west side. It extends from Knights Landing in the south to the vicinity of Princeton on the north. This depression has been constructed geologically by the building up of the banks of the Sacramento River by deposits made during the overflow of flood waters. The flood flow of the Sacramento River in this vicinity far exceeds the capacity of the channel and under natural conditions in the past, has overflowed its banks, for this entire distance. The deposits of silt from the flood waters, as the velocity reduces on overflowing the banks, has built up the banks of the river to a height from 5 to 15 feet higher than the land two or three miles westerly from the river bank. The slope of the land is therefore away from the river bank in a general westerly direction. This slope intersects the slope of the main valley floor extending from the foothills towards the river. The intersection of these two slopes has made a more or less irregular but consecutive depression, paralleling the general direction of the river for the entire length of the basin. The flood water overflowing the banks of the river, together with the run-off from the foothills and coast range mountains, west of Colusa Basin, cause a large flow of water down this depression in the winter and spring months. A natural ridge extending easterly from the foothills on the coast range to the banks of the Sacramento River intercepts this flow of water and turns it into the river channel at Knights Landing.

These flood waters pass down Colusa Basin inundating large areas. On the recession of the floods the last water seeks the lowest depression following what has been termed the "trough" on its way to the river at Knights Landing. This trough in general is nothing more than an intersection of the two flat slopes, one from the foothills towards the river, and the other from the river towards the foothills. Portions of the basin which have considerable longitudinal grade, and where the waters obtained an eroding velocity, are scoured to form a definite channel with banks conspicuous to the eye. Of the total length of Colusa Basin perhaps half of it is traversed by a definite channel with banks.

The construction of Reclamation District No. 108 and District No. 787 has placed levees on the westerly side of this basin so that since this construction was completed the waters flowing down the trough are

prevented from following the natural channel. These levees deflect the water causing it to follow on the westerly side of and in the borrow pit of these levees. Thus for a distance of 12 or 15 miles in that portion of the basin where the natural channel is most distinctly defined, the waters flowing down Colusa Basin are prevented from following the channel by the construction of these reclamation districts. The water in following down the borrow pit of the levees of these districts also enters the river at Knights Landing at a point about 200 feet from the mouth of the natural channel.

The development of rice culture in Colusa Basin has caused a flow of drainage water down the trough in the late summer and fall of the year. At this time of the year under natural conditions, the trough is always dry, there being no surface runoff from the Coast Range Mountains nor overflow from the Sacramento River. The large area planted to rice in 1920 caused a flow reaching a maximum of perhaps 1500 second-feet during the first week in October. This flow started in some quantity about the middle of July and was picked up and used for irrigation water by any parties desiring it whose land the water crossed.

Due to the fact that this water is not confined to a channel but in places spreads over a considerable area and has prevented the harvesting of a considerable acreage of rice each season, by keeping it flooded during the harvest period, the property holders of Colusa Basin have united in the organization of Drainage District No. 2047 for the purpose of constructing canals to carry off this drainage water without damage to the land which it crosses. The district contemplates the construction of a main canal with a capacity of 1500 second-feet following the present trough of Colusa Basin, southerly, to a point on the west levee of Reclamation District No. 108. The water will be taken under the levees of District No. 108 through culverts and carried to a pumping plant on the banks of the Sacramento River at Rough and Ready Landing. This pumping plant will be erected by the drainage district in cooperation with Reclamation District No. 108. Waters in excess capacity of this pumping plant will follow the present course along the borrow pit of the west levees of the district to Knights Landing and thence escape into the river. Main lateral canals will be constructed by the district in places considered necessary. The system of drainage contemplated will greatly facilitate the passage of flood waters during the winter by confining the last flow of the flood waters in definite channels, permitting access to the lower lands of the basin at an earlier date than would otherwise be possible. The district has already let contracts for the construction of the main canal and is preparing to let contracts on the culverts and pumping plant.

The Reclamation District has acquired rights of way from the property holders for the territory traversed by their canals. These right-of-way conveyances contain clauses similar to the following, which is an extract from one of the deeds:

* * * and said grant is made upon the condition that said district shall construct said canal within a reasonable time, and so construct the same so as to reasonably protect the remainder of the lands of grantor of which the contract over which said right of way is granted forms a part from overflow from drainage water from the lands of said district, and this conveyance shall not be constructed or construed as a waiver of any right of action against said district or any other person or persons as damages to the remainder of said lands of grantors by reason of overflow from drainage waters from the lands in said district.

Said parties of the first part reserve the right to use any or all waters that they can or may lawfully use that flow down said canal, and this grant or right of way does not interfere with any of the original rights or water rights of the grantors to said lands adjacent to said right of way hereby granted.

It is commonly conceded by everyone in the vicinity that individual property holders have the right to enjoin those above them from draining their water down through the trough of Colusa Basin over their lands. The conveyances of rights of way to the district are conditioned that the district protect the individual property holders from damage by this drainage water through the construction of canals. The conveyances also specify that all rights that they may have to the use of this drainage water are reserved by the property holders.

APPENDIX L.

THE COLORADO RIVER.*

By W. A. JOHNSTONE, *Commissioner.*

One of the most interesting if not the most important stream problem with relation to irrigation and power development is this great river.

From its mouth at the head of the Gulf of California in Mexico to the junction of the Green and Grand rivers in southeastern Utah the stream is known as the Colorado. Above this the west fork of the stream, with its headwaters in the mountains of western Wyoming, is known as the Green River, and this is the main continuation of the Colorado. The total length of the river from the gulf is 1700 miles. The eastern fork, rising mainly in Western Colorado, is known as the Grand River, and in size is almost equal to the Green. These streams have their sources in mountains approximating 14,000 feet elevation, and in their courses to their junction fall about 10,000 feet. The elevation at the junction is 3900 feet. From the junction of the Green and the Grand to the gulf the stream is roughly 1000 miles in length. Both of the upper streams as well as the main Colorado River have large and important affluents. The region drained by these streams covers part of six great states including all of Arizona and a small portion of Mexico, a region roughly 800 miles long and from 300 to 500 miles wide, comprising nearly a quarter of a million square miles. In its course the river travels southwesterly down the huge topographic stairway formed by the successive plateaus from the great central tableland of the continent to the gulf. Through these steps and tablelands the river has cut enormously deep channels and has in the course of the ages carried the spoil down to the ancient seashore. Here this rich sediment was deposited as a great delta and cut off from the parent sea, the Coahulla Lake, now known as Salton Sea, and built up a great detrital cone extending southward into the gulf. Along the back of this cone the Colorado River now rides in its course to salt water. It is an unruly stream and frequently exerts its will in defiance of all control, spreading over vast areas of its domain and doing incalculable damage to irrigation and other works of man.

The waters of the river are rich in sedimentary silts greatly enriching the soils over which it is spread. The rich and hot interior valleys of

* Much of the data utilized in this paper was obtained from Water Supply Paper 395, U. S. Geological Survey, by E. C. La Rue.

California and Arizona, as well as the detrital plains in Mexico, offer ideal situations for the application of its full resources in agriculture. The fall of the river over the great steps provides wonderful possibilities for power development at a thousand sites. In addition, Nature has provided along the course of this great river many very great storage sites.

Man has already demonstrated the possibilities of the agricultural development of the stream from the high mountain valleys to the great, fertile but dormant valleys in Arizona and California, and the vast flows of the river furnish an available supply.

Many thriving cities with mines, mills and factories, as well as four great transcontinental railroads, occupy and traverse this great region making an already great market available for hydroelectric power.

It remains then for man to control and harness this great stream and realize its tremendous potentialities.

The great river has been poetically described by Powell in his "Canyons of the Colorado" thus: "Fed by a group of little alpine lakes that receive their waters directly from perpetual snows. * * * When the summer comes this snow melts and tumbles down the mountain sides in millions of cascades. A million cascade brooks unite to form a thousand torrent creeks; a thousand torrent creeks unite to form half a hundred rivers beset with cataracts; half a hundred warring rivers unite to from the Colorado which flows, a mad, turbid stream, into the Gulf of Mexico."

The problem of control and regulation of the river involves many complicated questions, state, interstate, national and international in character. It seems reasonable to assume that any comprehensive scheme must be initated and carried out by the federal government through its Reclamation Service or other special agency. It is also apparent that this should be undertaken with the cooperation of the interested states at an early date. Already projected development, as well as projects now going, are becoming more and more dependent upon storage for late summer uses, and as time advances the friction over late flows and priorities as to their use will become more and more acute. As the country grows the latent possibilities in the production of power without fuel consumption, as well as foods and textile materials, accentuates the need for continued and thorough engineering investigation by the federal government at an early date.

In California, the Imperial Irrigation District waters upwards of half a million acres of land of great fertility, and under the United States Reclamation Project at Yuma a large acreage is under irrigation both in California and Arizona. The Blythe project is rapidly enlarging

into a development of the first importance. Applications are before the State Water Commission for permits to water the great Palo Verde Mesa and Chuckawalla Valley, nearly all the land of which has been taken up under desert entry and awaits the development of a practical method of securing and applying the needed water from the Colorado River. There is an ample supply during the early summer freshets which reach their peak about the twenty-fifth of June, but the rapidly receding late summer flows are already fully taxed to meet the requirements of the established developments, so that further extensions must rely upon storage.

As has been pointed out, the possibilities for storage on the upper river are ample for both flood control, irrigation and power development. It is estimated that over 2,000,000 acres are available for irrigation from the lower reaches of the river alone. The power possibilities are, as yet, conjectural, but very great.

With distant upper storage calling for release and control of the released flows from the reservoir through possibly a thousand miles of channel with interstate and international rights involved, the problem calls for a development under the authority of the federal government. No single state would have the jurisdiction or ability to handle such a vast undertaking.

APPENDIX M.

PROPOSED WATER MASTER BILL.

To amend an act known as the "Water Commission Act," approved June 16, 1913, amending section thirty-seven thereof and adding five new sections, to be numbered thirty-seven a, thirty-seven b, thirty-seven c, thirty-seven d, thirty-seven e, relating to the distribution of water and providing for the appointment of water masters and defining their duties.

The people of the State of California do enact as follows:

SECTION 1. Section thirty-seven of an act known as the "Water Commission Act," approved June 16, 1913, is hereby amended to read as follows:

Sec. 37. The State Water Commission shall divide the state into water districts to be so constituted and adjusted as to insure the most practical and economical supervision of the distribution of water on the part of the state, and shall have authority to make such reasonable regulations to secure the equal and fair distribution of water in accordance with the determined rights as may be needed. Said water districts shall not be created until a necessity therefor shall arise and shall be created and changed from time to time as the claims to water shall require.

SEC. 2. A new section is hereby added to said act, to be numbered section thirty-seven *a*, and to read as follows:

Sec. 37*a*. One or more water masters for each water district shall be appointed by the State Water Commission. The water master shall be properly qualified and shall perform the duties imposed on him by this act as an employee under the general supervision and control of the State Water Commission. It shall be the duty of the water master to divide the waters of the streams, or other sources of supply, among the several conduits, ditches, pipe lines and other means of diversion (all of which are hereinafter referred to as conduits) and reservoirs taking water therefrom, according to the rights of the water users as fixed by the permits or licenses issued by the State Water Commission, determinations of rights under this act, or the adjudications of the courts, and to so adjust or close the headgates of conduits, and regulate the controlling works of reservoirs, as may be necessary to insure a proper distribution of the water thereof among the water users entitled to its use. Whenever, in the pursuance of his duties, the water master regulates a headgate to a conduit or the controlling works of reservoirs, it shall be his duty to attach to such headgate or controlling works a written notice properly dated and signed, setting forth the fact that such headgate or controlling works has been properly regulated and is wholly under his control, and such notice shall be a legal notice to all parties interested in the diversion and distribution of the water of such conduit or reservoir.

SEC. 3. A new section is hereby added to said act, to be numbered section thirty-seven *b*, and to read as follows:

Sec. 37*b*. Any person who shall wilfully and without auothority open, close, change or interfere with any headgate, water-box or measuring device while under the control of the water master, or who shall wilfully take or use water which has been denied him by the water master under the provisions of this act, shall be deemed guilty of a misdemeanor. The possession or use of water when the same shall have been so denied him by the water master shall be prima facie evidence of the guilt of the person using it.

SEC. 4. A new section is hereby added to said act to be numbered section thirty-seven *c*, and to read as follows:

Sec. 37*c*. The owner of any conduit shall construct and maintain to the satisfaction of the State Water Commission a substantial and serviceable headgate or diversion works, at or near the point where the water is diverted, which shall be of such construction that it can be locked and kept closed by the water master; and such owners shall construct and maintain, when required by the State Water Commission, suitable measuring devices at such points along such ditch as may be necessary for the purpose of assisting the water master in determining the amount of water that is to be diverted into said conduit from the stream. Any and every owner or manager of a reservoir located across or upon the bed of a natural stream or of a reservoir which requires the use of a natural stream channel, shall construct

and maintain, when required by the State Water Commission, a measuring device of a plan to be approved by the State Water Commission, below such reservoir, and a measuring device above such reservoir on each or every stream or source of supply discharging into such reservoir, for the purpose of assisting the State Water Commission or water master in determining the amount of water to which appropriators are entitled and thereafter diverting it for such appropriator's use. If any such owner or owners of water works shall refuse or neglect to construct and put in such headgates or measuring devices after thirty days' notice, the water master may close such ditch, and the same shall not be opened or any water diverted from the source of supply, under the penalties prescribed by law for the opening of headgates lawfully closed until the requirements of the State Water Commission as to such headgates or measuring device have been complied with, and if any owner or manager of a reservoir located across the bed of a natural stream, or of a reservoir which requires the use of a natural stream channel, shall neglect or refuse to put in such measuring devices after thirty days' notice by the State Water Commission, the water master may open the sluice-gate or outlet of such reservoir and the same shall not be closed, except by order of the State Water Commission, under the penalties of the law for changing or interfering with headgates, until the requirements of the State Water Commission as to such measuring devices are complied with.

SEC. 5. A new section is hereby added to said act, to be numbered section thirty-seven *d*, and to read as follows:

Sec. 37*d*. The water master shall have the power to arrest any person violating any of the provisions of sections thirty-seven *b* and thirty-seven *c* of this act, and to give him into the custody of the sheriff, or other competent police officer within the county, and immediately thereafter make complaint before a magistrate against the person so arrested.

SEC. 6. A new section is hereby added to said act, to be numbered section thirty-seven *e*, and to read as follows:

Sec. 37*e*. Any person violating any of the provisions of sections thirty-seven *b* and thirty-seven *c* of this act shall be deemed guilty of a misdemeanor, and upon conviction thereof shall be fined in a sum not less than twenty-five dollars, nor more than two hundred fifty dollars, or imprisoned in the county jail not less than ten days nor more than six months, or by both such fine and imprisonment.

TABLE 3.

List of Important Proposed Irrigation Projects as Indicated by Applications to Appropriate Water Filed During the Biennial Period Ending September 1, 1920

Name of applicant	Application number	County	Source of supply	Amount of water		Area to be irrigated, acres	Estimated cost
				Natural flow, second feet	Storage, acre feet		
Walter H. Chase	1073	Modoc	Ash Creek	97	67,000	47,000	$335,000
Alameda Sugar Company	1074	Sutter	Sacramento River	142		7,600	287,000
Walter H. Chase	1080	Modoc	South Fork Pit River	524		40,000	208,000
Oakdale Irrigation District	1081	Calaveras, Tuolumne	Stanislaus River		96,185	75,000	2,000,000
W. F. Simpson and J. I. Wilson	1082	Mono	Leavitt Meadows	190		20,000	250,000
K. E. Enslow et al	1095	Plumas, Butte	Middle Fork Feather River	900	60,000	35,320	500,000
W. M. Kearney	1097	Mono	W. Walker River	1,000	35,000	28,500	300,000
W. M. Kearney	1098	Mono	W. Walker River	1,000	115,000	28,500	200,000
Coachella Valley Water District	1122	Riverside	White Water River and Snow Creek	400		25,000	10,000
Honcut-Yuba Irrigation District	1133	Yuba	Yuba River	500		25,000	500,000
John K. Eneboe	1141	Lassen	Red Rock Creek	50		3,240	50,000
Wm. R. Wright	1147	Los Angeles	San Gabriel River		40,000	17,500	2,500,000
Sutter-Butte Canal Company	1149	Sutter	Feather River	500		27,500	
S. Sweet Company	1150	Yolo	Borrow Pit of Recl. Dist. No. 999	80		3,698	20,000
W. H. Chase	1154	Modoc	Crooks Canyon		15,000	4,000	80,000
D. C. Shetler	1197	Mariposa	Chowchilla River		60,000	15,000	40,000
Conaway Ranch	1199	Yolo	Sacramento River	120		3,120	100,000
Natomas Company of California	1203	Sacramento	Sacramento River	160		14,510	350,000
Leon Bly	1209	Lassen	Eagle Lake		30,000	25,000	1,000,000
Frank B. Attee et al	1214	Calaveras	Stanislaus River	130	31,957	74,246	2,000,000
Honcut-Yuba Irrigation District	1216	Butte	Feather River	1,000		50,000	332,132
Merced Irrigation District	1224	Merced	Merced River	2,500	700,000	200,000	12,000,000
Turlock Irrigation District	1233	Tuolumne	Tuolumne River		600,000	200,000	*1,550,000
G. Albert Smith	1241	Kings	Kings River	700	3,300	44,800	
Sespe Light and Power Company	1250	Ventura	Sespe Creek	250			
J. F. O'Connor	1270	Nevada	Canyon Creek	500	125,000		
Honcut-Yuba Irrigation District	1275	Yuba	Yuba River	500		50,000	509,247
W. A. Beard	1279	Tehama	Sacramento River	2,500	1,000,000	300,000	37,577,932
Diamond Ridge Water Company	1285	El Dorado	North Fork Cosumnes River	97	32,500	30,000	992,116
Diamond Ridge Water Company	1289	El Dorado	North Fork Cosumnes River	72	8,300		320,647
Diamond Ridge Water Company	1290	El Dorado	Camp Creek	113	11,000		321,840

*Estimated cost includes power development.

J. B. Thompson	1292	Butte	Sacramento River	800		50,123	2,530,000
Alfred C. Gregory	1297	Solano	Lindsay Slough	400		44,000	1,000,000
Sespe Light and Power Company	1319	Ventura	Piru Creek	286	60,000		
W. J. & P. S. Dorris	1321	Modoc	Parker Creek	57	12,000	4,170	15,000
J. B. Thompson	1356	Lassen, Shasta	Butte Lake	400	50,000	50,123	207,500
Harmon Stuver	1360	Modoc	Big Sage Reservoir Site		77,000	9,600	92,500
Arthur W. Goodfellow-L. A. Nares	1369	Kings	Beall Slough, Kings River	500	45,000	45,000	200,000
Guy Wilkinson	1368	Butte	Lost and Pinckard Creeks	200		20,000	
Walker River Irrigation District	1389	Mono	E. Walker River	381	80,000		
Walker River Irrigation District	1390	Mono	Green Creek	119	25,000		
Walker River Irrigation District	1391	Mono	Robinson Creek	119	25,000		
Walker River Irrigation District	1394	Mono	Virginia Creek	119	25,000		
Walker River Irrigation District	1395	Mono	Buckeye Creek	119	25,000		
Walker River Irrigation District	1396	Mono	Robinson Creek	95	20,000		
Natomas Company	1413	Sutter	Sacramento River	120		10,140	300,000
United States Reclamation Service	1414	Glenn, Colusa, Tehama	Stony Creek		104,000	25,000	2,000,000
Bear River Water and Power Co.	1417	Placer, Nevada	Bear River	250	100,000	25,000	
R. G. Kann	1418	Calaveras	Black Creek	300		7,000	100,000
Geo. F. Cokely	1421	Fresno	Panoche Creek		12,000	6,720	75,000
South San Joaquin Irrigation Dist.	1424	Calaveras	Little Johns's Creek		100,000	143,000	750,000
South San Joaquin Irrigation Dist.	1427	Calaveras	Black Creek		46,000	143,000	1,250,000
C. W. Hatch and R. V. Melkle	1442	Merced	Merced River	94		7,664	150,000
South San Joaquin Irrigation Dist.	1446	San Joaquin	Stanislaus River	150		15,000	50,000
Modesto Irrigation District	1456	Tuolumne	Tuolumne River		600,000	100,000	3,100,000
Mokelumne R. Power and Water Co.	1462	Calaveras	Mokelumne River	500		75,000	
Madera Irrigation District	1465	Madera	San Joaquin River	5,000	1,150,000	350,000	15,000,000
Guy T. Wayman	1467	Shasta	Fall River	250		20,000	60,000
C. Pucheu and E. F. Mitchell	1470	Fresno	Fresno Slough	400		100,000	500,000
Merced Irrigation District	1473	Merced	Merced River	2,500	600,000	180,000	5,500,000
Roy M. Pike	1476	Stanislaus	San Joaquin River	75		4,000	125,000
Madera Irrigation District	1496	Madera	Fresno River	250	150,000	10,000	
Lloyd McAulay	1500	Fresno, Merced, Stanislaus	San Joaquin River	500		35,681	1,000,000
Egbert J. Gates	1507	Calaveras	South Fork Calaveras River		100,000	50,000	
F. G. Athearn	1513	Madera, Merced, Mariposa	Chowchilla River		60,000	13,560	400,000
Finnell Land Company	1521	Tehama	Elder Creek	50		2,000	15,000
Kern Delta Irrigation District	1548	Kern, Tulare	Kern River		1,500,000	400,000	15,000,000
Williams Irrigation District	1554	Colusa	Colusa Basin, Sacramento River	187		7,480	
U. B. Tyler	1560	Tehama	Sacramento River	50		2,665	65,000
Modoc County Development Board	1577	Lassen	Ash Valley Drainage		75,000	14,300	
Geo. W. Moore	1578	Colusa	Trough of Colusa Basin	224		8,960	10,000
Conaway Ranch	1588	Yolo	Sacramento River	200		16,194	600,000

TABLE 3—Continued.

List of Important Proposed Irrigation Projects as Indicated by Applications to Appropriate Water Filed During the Biennial Period Ending September 1, 1920

Name of applicant	Application number	County	Source of supply	Amount of water		Area to be irrigated, acres	Estimated cost
				Natural flow, second feet	Storage, acre feet		
Reclamation District No. 108	1589	Colusa	Sacramento River	300		58,160	130,000
Allen Talbott	1600	Tuolumne	Tuolumne River	10,000	120,000	160,000	16,000,000
South Feather Land and Water Co.	1608	Butte	South Fork Feather River		50,000	30,000	1,000,000
F. L. Fehren	1609	San Joaquin	San Joaquin River	100		9,000	350,000
Excelsior Water and Mining Co.	1614	Nevada	Deer Creek		68,000	22,000	1,900,000
Excelsior Water and Mining Co.	1614	Nevada	Deer Creek	100			
Excelsior Water and Mining Co.	1615	Nevada	Deer Creek	125			
Frank Buren and Mason Bradfield	1620	Ventura	Piru Creek	250		10,000	
Williams Irrigation District	1624	Colusa	Colusa Basin, Sacramento River	65		2,598	
J. M. Wright	1635	Los Angeles	Big Rock Creek		50,000	10,000	800,000
Natomas Company	1636	Sutter	Feather River	90		7,258	216,000
K. E. Enslow	1637	Butte	Fall River	61	20,000	7,040	300,000
W. E. Bunker and A. P. Miller	1638	Madera, Fresno	San Joaquin River	2,500	400,000	208,000	
Honcut-Yuba Irrigation District	1646	Butte	North Honcut, South Honcut and Wyandotte Creeks		100,000	30,000	
Logan Cecil et al	1647	Colusa	Sacramento River	51		880	10,000
Oroville-Wyandotte Irrigation Dist.	1651	Plumas	South Fork Feather River	5,000	300,000	20,000	
Crooks Canyon Irrigation District	1657	Modoc	Crooks Canyon		9,617	4,019	77,330
Sebia Davis	1659	Colusa	Sacramento River	160		6,400	
Reclamation District No. 999	1666	Yolo, Solano	Elk, Sutter and Miner's Sloughs, Sacramento River	250		25,000	92,000
E. C. McClellan	1671	Tulare	Kaweah and Tule Rivers	1,950	200,000	300,000	8,000,000
I. G. Zumwalt	1687	Colusa	Colusa Trough	165		4,290	125,000
Honcut-Yuba Irrigation District	1688	Yuba	Indiana Creek		100,000	30,000	
Honcut-Yuba Irrigation District	1689	Yuba	Dry Creek		100,000		
Sutter Investment Company	1699	Sutter	Feather River	56		2,800	35,000
E. A. Bridgeford	1718	Contra Costa	Indian Slough, Marsh Creek	200		9,000	
Merced Irrigation District	1722	Merced	Burns Creek	500		178,000	
Merced Irrigation District	1723	Merced	Black Rascal Creek		80,000		
W. P. Dwyer	1725	Colusa	Borrow Pit Recl. Dist. No. 108	60	2,500	1,816	1,000
Lars R. Jorgensen	1728	Butte, Plumas	Feather River	450	100,000	125,000	2,000,000
Lars R. Jorgensen	1729	Yuba, Sierra	Yuba River	500	108,000	140,000	1,500,000
Yuba-Nevada-Sutter W. and P. Assn.	1735	Nevada	Bear River	175	65,000		

Yuba-Nevada-Sutter W. and P. Assn.	1736	Nevada, Sierra	Middle Fork Yuba River	150	5,400	6,000	1,800,000
T. A. Kilkenny	1737	Lake, Napa, Solano	Putah Creek	1,667	120,000	20,000	300,000
Merriam J. Howells	1739	Butte	Concow Reservoir Site	50	20,000	8,000	----------
E. A. Stellar	1740	Los Angeles	Big Rock Creek	----------	50,000	13,000	750,000
Wm. R. Wright	1751	Los Angeles	San Gabriel River	----------	15,000	20,000	1,000,000
Stewart S. Hawley	1753	Yolo	Sacramento River	57	----------	2,023	60,000
Happy Valley Irrigation District	1774	Shasta	North Fork Cottonwood Creek	75	----------	18,110	185,000
J. W. Leventon et al	1792	Modoc	Pit River	----------	75,000	14,600	----------
Honcut-Yuba Irrigation District	1795	Yuba	Dry Creek	----------	65,000	27,500	517,991
Terra Bella Irrigation District	1796	Tulare	Deer Creek	----------	20,000	12,500	2,000,000
W. D. Russell et al	1797	Lake	North Fork Cache Creek	----------	500,000	50,000	1,000,000
Geo. T. Dunlap	1803	Tehama	Thomas Creek	1,000	210,000	70,000	----------
Harry S. Riddell	1810	Shasta	Cottonwood Creek	300	100,000	40,000	600,000
Walter O. Crosby and G. C. Estes	1817	Amador	Cosumnes River	1,667	300,000	100,000	----------
Frank Gillelen	1832	Ventura	Sespe and Piru Creeks	200	150,000	10,800	----------
A. S. White	1834	San Joaquin	Old River	100	----------	8,350	327,000
W. A. Beard	1841	Tehama	Thomas Creek	750	125,000	50,000	----------
W. A. Beard	1842	Tehama	Elder Creek	600	100,000	40,000	----------
W. A. Beard	1843	Tehama	Red Bank Creek	400	75,000	30,000	----------
W. A. Beard	1844	Tehama	South Fork Cottonwood Creek	250	75,000	30,000	----------
W. A. Beard	1845	Tehama	Sacramento River	670	775,100	650,000	37,577,932
Escondido Mutual Water Company	1848	San Diego	San Luis Rey River	80	20,000	11,330	575,500
Dave Hirstel	1871	Napa	Milliken Creek	155	18,350	----------	----------
Guy T. Wayman	1874	Shasta	Fall River	196	----------	15,688	240,000
Jas. J. Stevinson	1885	Merced	Merced River	100	----------	6,490	75,000
Chas. E. Swezy	1898	Trinity	Trinity River	1,500	----------	50,000	1,500,000
Eugene E. Clark	1904	Sierra	Slate Creek	100	30,000	10,000	900,000
Fred H. Rindge	1911	Calaveras	Esperanza Creek, Quintal's Gulch	50	----------	800	50,000
Jens. Molgaard	1928	Monterey	Arroyo Seco River	----------	55,000	30,000	1,000,000
Oroville-Wyandotte Irrigation Dist.	1931	Butte	Fall Creek	500	100,000	20,000	----------
Oroville-Wyandotte Irrigation Dist.	1932	Plumas	Slate Creek	----------	100,000	----------	----------
Wm. Schlossman	1933	San Joaquin	Salmon Slough, Old River	250	----------	20,000	----------
Lars R. Jorgensen	1936	Sierra	North Fork Yuba River	----------	75,000	35,000	750,000
Mary Ives Crocker, J. W. Preston, Jr.	1938	Amador	Sutter Creek	100	50,000	16,000	----------
Madera Irrigation District	1945	Mariposa	South Fork Merced River	2,500	100,000	120,000	----------
Madera Irrigation District	1946	Mariposa	Big Creek	2,500	100,000		
Glenn-Colusa Irrigation District	1948	Shasta	Pit and Fall Rivers	----------	1,000,000	500,000	6,300,000
The Meek Estate	1952	Yolo	Sycamore Slough	50	----------	2,023	90,000
Roy E. Swigart	1959	Siskiyou, Cal., Klamath, Ore.	Klamath River	1,500	1,000,000	197,000	15,000,000
F. M. Hackler	1960	Shasta	Silver Lake	75	----------	5,000	50,000
Mary Ives Crocker, J. W. Preston, Jr.	1964	Amador	Mokelumne River	500	200,000	50,000	----------

TABLE 3—Concluded.

List of Important Proposed Irrigation Projects as Indicated by Applications to Appropriate Water Filed During the Biennial Period Ending September 1, 1920

Name of applicant	Application number	County	Source of supply	Amount of water		Area to be irrigated, acres	Estimated cost
				Natural flow, second feet	Storage, acre feet		
Browns Valley Irrigation District	1967	Yuba	Little Oregon Creek		50,000	11,500	
G. W. Peer and H. L. Berkey	1972	Plumas, Sierra	Gold Lake	600		24,000	
Madera Irrigation District	1973	Madera	Chowchilla River	500	60,000	31,400	
Madera Irrigation District	1974	Merced	Chowchilla River	500	60,000		
Lars R. Jorgensen	1978	Sierra, Plumas	Gold Lake, Long Lake, etc.		27,900	10,000	300,000
Fred J. Willis	1982	Los Angeles	San Gabriel River		35,000	17,000	2,600,000
Browns Valley Irrigation District	1986	Yuba	North Yuba River	63		40,000	
Wilhelm Schmidt	1987	San Joaquin	San Joaquin and Old Rivers	500		30,000	

TABLE 4.

List of Important Proposed Hydro-Electric Power Projects as Indicated by Applications to Appropriate Water Filed During the Biennial Period Ending September 1, 1920.

Name of applicant	Application number	County	Source of supply	Amount of water		Theoretical horsepower to be developed	Estimated cost
				Natural flow, second feet	Storage, acre feet		
Dudley Moulton	1086	Shasta	Pit River	2,000		29,090	$1,250,000
Frank B. Attee et al.	1157	Calaveras and Tuolumne	North Fork Stanislaus River	130	31,957	9,600	2,000,000
E. N. Rector	1221	Mariposa	Merced River	1,200	700,000	10,000	1,500,000
E. N. Rector	1222	Mariposa	Merced River	1,200	700,000	45,000	2,300,000
Turlock Irrigation District	1232	Tuolumne	Tuolumne River		600,000	45,000	2,550,000
Utica Mining Company	1243	Calaveras	North Fork Stanislaus River	162	62,886	35,350	1,360,410
Modesto Irrigation District	1259	Tuolumne	Tuolumne River		600,000	45,000	2,550,000
George Watterson	1278	Mono	Owens River	200		28,773	3,000,000
W. A. Beard	1280	Tehama	Sacramento River	10,000	1,000,000	108,000	17,977,013
Arthur L. Coggins	1293	Siskiyou	Upper Sacramento River	1,200		10,000	431,900
Lars R. Jorgensen	1303	Yuba	North Fork Yuba River	460		7,730	1,000,000
Sespe Light and Power Company	1317	Ventura	Sespe River	250		16,420	4,023,000
Sespe Light and Power Company	1318	Ventura	Piru Creek	286	60,000	57,900	
Sierra & San Francisco Power Co.	1339	Tuolumne	South Fork Stanislaus River	150		67,232	740,000
Southern California Edison Co.	1341	Fresno	Mono Creek	300	193,000	202,000	Total cost, 1341-1354, inclusive, about $200,000,000
Southern California Edison Co.	1342	Fresno	Bear Creek	600		131,000	
Southern California Edison Co.	1343	Fresno	South Fork San Joaquin River	1,000	32,200	371,000	
Southern California Edison Co.	1344	Fresno	South Fork San Joaquin River	1,000	43,200	41,000	
Southern California Edison Co.	1345	Fresno	Pitman Creek	250	3,800	81,000	
Southern California Edison Co.	1346	Fresno	Stevenson Creek	1,500	138,600	248,000	
Southern California Edison Co.	1347	Madera	North Fork San Joaquin River	450		69,000	
Southern California Edison Co.	1348	Madera	Middle Fork San Joaquin River		22,000	42,000	
Southern California Edison Co.	1349	Madera	West Fork Granite Creek	300		86,000	
Southern California Edison Co.	1350	Madera	Jackass Creek		27,000	14,000	
Southern California Edison Co.	1351	Madera	Middle Fork San Joaquin River	500		99,000	
Southern California Edison Co.	1352	Madera	Chiquito Creek		15,000	55,000	
Southern California Edison Co.	1353	Fresno	South Fork San Joaquin River	500		89,000	
Southern California Edison Co.	1354	Fresno and Madera	San Joaquin River		26,600	300,000	
Dennis Murphy	1376	Tehama	Deer Creek	150		13,400	1,000,000
H. L. Shannon	1381	Tehama	Deer Creek	200		22,700	500,000
Bear River Water and Power Co.	1416	Placer and Nevada	Bear River	250	100,000	70,000	

TABLE 4—Concluded.

List of Important Proposed Hydro-Electric Power Projects as Indicated by Applications to Appropriate Water Filed During the Biennial Period Ending September 1, 1920.

Name of applicant	Application number	County	Source of supply	Amount of water		Theoretical horsepower to be developed	Estimated cost
				Natural flow, second feet	Storage, acre feet		
Western States Gas & Electric Co.	1439	Eldorado	South Fork American River	230	------	18,820	1,000,000
Western States Gas & Electric Co.	1440	Eldorado	South Fork American River	230	------	60,000	2,500,000
Western States Gas & Electric Co.	1441	Eldorado, Alpine, Amador	Medley, Echo, Twin and Silver Lakes, Alder and Plum Creeks	271	74,000	22,621	1,500,000
R. W. Hawley	1458	Eldorado	Silver Creek	650	------	86,000	4,575,000
San Joaquin Light & Power Corp.	1463	Fresno	San Joaquin River	400	3,200	35,675	------
Mokelumne Power and Water Co.	1477	Calaveras	South Fork Mokelumne River	25	1,500	12,750	186,000
Mokelumne Power and Water Co.	1478	Calaveras	North Fork Mokelumne River	150	18,000		502,500
Mokelumne Power and Water Co.	1479	Calaveras	Middle Fork Mokelumne River	200	40,000	6,700	600,000
Mokelumne Power and Water Co.	1480	Calaveras	North Fork Calaveras River	100		32,250	25,000
Mokelumne Power and Water Co.	1481	Calaveras	North Fork Calaveras River	250			75,000
Mokelumne Power and Water Co.	1482	Calaveras	South Fork Mokelumne River	200			650,000
R. G. McDonald	1508	Mono	West Walker River	300	95,000	30,000	4,500,000
Turlock Irrigation District	1532	Tuolumne	Tuolumne River	4,000	600,000	45,000	1,000,000
Kern Delta Irrigation District	1547	Kern and Tulare	Kern River	2,000	1,500,000	150,000	*15,000,000
Modesto Irrigation District	1568	Tuolumne	Tuolumne River	4,000	600,000	45,000	1,000,000
Southern Sierras Power Company	1570	Mono	Convict Creek	45	15,453	14,077	------
William A. Royce	1584	Mono	Hilton Creek	18	8,000	5,600	------
William A. Royce	1585	Mono	McGee Creek	20	6,000	5,300	------
Allen Talbot	1599	Tuolumne	Tuolumne River	10,000	100,000	120,000	16,000,000
C. R. Gallfus	1601	Tuolumne	Tuolumne River	10,000	100,000	120,000	16,000,000
Sespe Light and Power Company	1619	Ventura	Piru Creek	250	------	------	------
City of Los Angeles	1629	Inyo	Rock Creek	------	14,500	6,790	350,000
City of Los Angeles	1639	Tulare	South Fork Kern River	------	25,000	45,000	3,000,000
Lars R. Jorgensen	1676	Plumas and Butte	Middle Fork Feather River	250	60,000	79,540	6,000,000
Lars R. Jorgensen	1677	Plumas and Butte	Middle Fork Feather River	450	40,000	59,800	4,500,000
Henry H. Wadsworth	1679	Sierra and Nevada	Yuba River	200	5,000	13,300	------
Henry H. Wadsworth	1680	Yuba	Yuba River	700	20,000	15,500	2,500,000
Lars R. Jorgensen	1708	Sierra	North Fork Yuba River	------	78,000	------	2,000,000
Snow Mt. Water and Power Co.	1719	Lake and Mendocino	South Fork Eel River	400	215,000	15,000	3,000,000
Francis O. Hatch	1777	Tehama	Mill Creek	100	200	12,210	2,500,000
S. E. Gettis	1793	Mendocino	North Fork Eel River	189	137,385	23,569	1,500,000

Frank Gillelen	1881	Ventura	Sespe and Piru Creeks	200	150,000	28,000	----------
H. L. Jackman	1947	Humboldt	Klamath River	9,000	150,000	306,180	20,000,000
City of Los Angeles	1857	Fresno	South and Middle Fks. Kings River	2,050	225,000	296,500	----------
City of Los Angeles	1858	Fresno	Kings River	1,600	20,000	170,000	----------
City of Los Angeles	1862	Mono	Rock Creek	25	40,000	15,000	1,000,000
Bear River Water and Power Co.	1866	Nevada and Placer	Deer Creek	1,050	----------	105,000	----------
City of Los Angeles	1867	Tuolumne	Tuolumne River and Return Creek	950	35,000	159,700	----------
City of Los Angeles	1868	Mariposa and Madera	Merced River	1,455	42,000	156,300	----------
A. P. Seybold	1890	Humboldt	Klamath River and Bluff Creek	5,200	10,000	30,000	2,000,000
Mt. Shasta Power Corporation	1891	Shasta	Pit River	3,000	50,000	72,000	----------
Mt. Shasta Power Corporation	1892	Shasta	Pit River	3,000	----------	42,000	----------
Lars R. Jorgensen	1899	Sierra	North Fork Yuba River	400	----------	15,876	1,400,000
Lars R. Jorgensen	1900	Sierra	North Fork Yuba River	250	80,000	36,855	4,000,000
San Joaquin Light & Power Corp.	1916	Fresno	Deer Creek	50	21,000	8,409	1,200,000
San Joaquin Light & Power Corp.	1917	Fresno	Deer Creek	60	5,000	8,834	1,200,000
San Joaquin Light & Power Corp.	1918	Fresno	North Fork Kings River	450	----------	7,102	3,000,000
San Joaquin Light & Power Corp.	1919	Fresno	North Fork Kings River	250	5,000	70,738	9,600,000
San Joaquin Light & Power Corp.	1920	Fresno	North and West Forks Kings River	300	5,000	85,568	11,000,000
San Joaquin Light & Power Corp.	1921	Fresno	Kings River	750	----------	35,795	4,850,000
Jens Molgaard	1927	Monterey	Arroyo Seco River	200	55,000	6,670	309,000
Lars R. Jorgensen	1937	Sierra	North Fork Yuba River	400	75,000	20,400	750,000
Francis O. Hatch	1949	Tehama	Mill Creek	200	200	24,200	2,500,000

*Estimated cost includes irrigation development.

TABLE 5.

List of Important Proposed Mining Developments as Indicated by Applications to Appropriate Water Filed During the Biennial Period Ending September 1, 1920.

Name of applicant	Application number	County	Source of supply	Amount of water		Estimated cost
				Natural flow, second feet	Storage, acre feet	
A. J. Barber	1228	Siskiyou	Canyon and Kelsey Creeks	125		$70,000
Gus Perigot	1384	Trinity	New River	125		75,000
Egbert J. Gates	1506	Calaveras	San Antonio River	125	10,000	
A. L. Fearrien	1593	Humboldt	Mill Creek	50		
H. W. A. Docker and O. A. Beaver	1597	Humboldt	Campbell Creek	50		10,000
W. B. Coombs	1598	Humboldt	Tish, Tang-a-Tang Creeks	75		20,000
H. C. Markley et al	1662	Sierra and Plumas	Gold, Long Lakes	500		10,000
P. P. Hammer	1709	Humboldt	Maddon Creek	50		5,000
Robert Duncan	1776	Humboldt	Mill Creek	50		10,000
Tom Traves Lane	1826	Plumas	Ward Creek	60		
Eugene E. Clark	1908	Sierra	Big Canyon, Slate, Esperanza Creeks	100	30,000	900,000
Fred H. Rindge and G. W. Peer	1912	Calaveras and Plumas	Quintal's Gulch	50		50,000
H. L. Berkey	1971	Sierra	Gold Lake and tributaries	600		

TABLE 6.

List of Important Proposed Municipal Projects as Indicated by Applications to Appropriate Water Filed with the State Water Commission in the Biennial Period Ending September 1, 1920.

Name of applicant	Application number	County	Source of supply	Amount of water		Population	Estimated cost
				Natural flow, second feet	Storage, acre feet		
City of Pasadena	1662	Los Angeles	Arroyo Seco	14.5		50,000	$290,000
Snow Mt. Water and Power Co.	1720	Lake and Mendocino	South Eel River	400		500,000	10,000,000
City of Sacramento	1743	Sacramento	Sacramento River	300		80,000	1,800,000
Coronado Water Company	1851	San Diego	Tia Juana Valley	7.7			125,000
City of Vallejo	1878	Napa	Milliken Creek	9.3	15,350		
City of Vallejo	1905	Napa	Milliken Creek	350	72,000	72,000	700,000
City of Vallejo	1907	Napa	Wooden Valley Creek	275	16,400		
City of Vallejo	1908	Napa	Creek flowing into Gordon Valley		37,000		
City of Vallejo	1909	Napa	Creek flowing into Gordon Valley		14,000		
Snow Mt. Water and Power Co.	1934	Mendocino	South Eel River	400			
Walter Wray, for city of Santa Ana	1950	Orange	Santiago Creek		40,000	18,000	
City of San Fernando	1977	Los Angeles	Pacoima Canyon	10	3,620	3,500	200,000
City of San Luis Obispo	1990	San Luis Obispo	Lopez Creek	4		7,500	

TABLE 7.

List of Important Permits to Appropriate Water Issued During Biennial Period Ending September 1, 1920.

Name of permittee	Permit No.	Application No.	County	Source of supply	Character of use	Extent of development		Length of canal or conduit, miles	Capacity of storage reservoir, acre feet	Estimated cost
						Acres	Theoretical horsepower			
The Nevada-California Power Co.	484	1026	Mono	Rush Creek	Power		1,000		8,763	$45,000
Horace L. Hill, Jr.	489	989	Yolo	Sacramento River	Agricultural	366				3,500
G. H. B. Conoles	491	964	Colusa	Hunters Creek	Agricultural	513		0.36		1,200
P. B. Cross	494	1047	Glenn	Sacramento River	Agricultural	8,436		14.00		100,000
Elliott Land Co.	499	823	Stanislaus	Amphir Cut	Agricultural	1,530		3.94		7,000
Elliott Land Co.	500	824	Stanislaus	Stanislaus River	Agricultural	1,093		2.13		5,500
Lucerne Water Co.	501	443	Siskiyou	Shasta River	Agricultural	4,144		5.00		50,000
Webb Bros. Co.	509	58	Siskiyou	Shasta River	Agricultural	463		4.00		12,000
Natomas Co.	511	1056	Sacramento	Sacramento River	Agricultural	3,522		5.50		90,000
Natomas Co.	512	1060	Sacramento	Sacramento River	Agricultural	239		0.69		6,000
Natomas Co.	513	1061	Sacramento	Sacramento River	Agricultural	838		1.63		21,000
Fred W. Kiesel	518	1094	Sacramento	Sacramento River	Agricultural	335		0.75		8,000
Happy Valley Irrigation District	531	782	Shasta	Hoover or Ducket Creek	Agricultural	18,110		25.00	1,166	91,000
Happy Valley Irrigation District	532	783	Shasta	NE. Fk. Cottonwood Ck.	Agricultural	18,110		25.00	740	50,290
Happy Valley Irrigation District	533	784	Shasta	NE. Fk. Cottonwood Ck.	Agricultural	18,110		25.00	5,700	312,400
Coachella Valley Co. Water Dist.	536	1122	Riverside	Whitewater R., Snow Ck.	Agricultural	25,000				10,000
Stanford University	542	1041	Tehama	Deer Creek	Agricultural	1,200		8.00		10,028
California National Gold M. Co.	545	1015	Butte	Berry Creek	Power		670	11.00		16,000
W. J. and P. S. Dorris	568	1108	Modoc	Rattlesnake Creek	Agricultural	618			1,392	5,000
Sutter Basin Improvement Co.	569	1160	Sutter	Sacramento River	Agricultural	3,240		1.00		65,000
Ed Ivory, Jr.	573	1164	Modoc	Rye Grass Swale	Agricultural	777		5.25	2,026	16,000
Thos. Hill	576	1101	Lassen	Lone Pine Reservoir	Agricultural	1,042		2.00	1,900	7,000
Thos. Hill	577	1102	Lassen	Rice's Canyon	Agricultural	1,042		0.80	452	6,000
T. T. C. Gregory	579	1198	Yolo	Sacramento River	Agricultural	782				4,000
Natomas Co. of California	580	1203	Sacramento	Sacramento River	Agricultural	14,510		10.87		350,000
Roy M. Pike	588	1195	Stanislaus	San Joaquin River	Agricultural	2,641		2.50		80,000
Alameda Sugar Co.	591	1074	Sutter	Sacramento River	Agricultural	8,613				287,000
San Joaquin Light & Power Corp.	606	829	Fresno	San Joaquin River	Power		27,841	3.40	3,200	4,000,000
E. M. Gordon	609	1179	Colusa	Port Wine Ravine	Agricultural	1,255		4.00		25,000
Loftus Blue Lead Mines Co.	612	1085	Sierra	Sacramento River	Mining			9.74		30,000
Conaway Ranch	614	1190	Yolo	Sacramento River	Agricultural	5,120		5.50		100,000

G. L. Kramer	618	1268	Modoc	Meade Flat Drainage Area	Agricultural	490		1.70	871	1,000
Western States Gas & Electric Co.	619	654	El Dorado, Alpine	Medley Lake	Power		2,500	7.30	5,000	202,375
				Echo Lake					7,000	
				Twin Lakes					8,000	
Maude Crouch Moore	632	1306	Butte	Sacramento River	Agricultural	700		2.60		3,000
S. Sweet Co.	640	1150	Yolo	Borrow Pit of Reclamation District No. 999	Agricultural	3,666		2.17		20,000
A. J. Barker	642	1228	Siskiyou	Canyon, Kelsey Creeks	Mining			20.00		70,000
R. T. Harding	648	1156	Plumas	Buck's Creek	Power		6,733	4.00		158,000
P. N. Ashley	656A	1177	Butte	Main Drainage Canal of Drainage Dist. No. 100	Agricultural	612		3.00		4,000
Samuel J. Nunn et al.	657	1299	Butte	Drain Ditch of Drainage District No. 100	Agricultural	296				1,500
Samuel J. Nunn	663	1415	Butte	Drain Ditch of Drainage District No. 100	Agricultural	296				1,500
Sierra & S. F. Power Co.	668	1339	Tuolumne	S. Fk. Stanislaus River	Power		31,704	17.63		740,000
San Joaquin Light & Power Co.	680	1463	Fresno	San Joaquin River	Power		35,795	3.40	3,200	4,000,000
E. C. Latchem	682	937	Siskiyou	Grouse Creek	Mining			1.25		1,000
I. G. Zumwalt	687	940	Colusa	Sacramento River	Agricultural	3,468		13.60		200,000
Sutter-Butte Canal Co.	688	1149	Butte	Feather River	Agricultural	27,500		23.00		40,000
Nevada-California Power Co.	689	1484	Inyo	McGee Creek	Power		1,340	0.24		12,000
F. A. Koetitz	692	1628	Stanislaus	Stanislaus River	Agricultural	240		1.75		5,000
Imperial Utilities Corp.	695	1486	San Bernardino	Mojave River	Municipal			0.57		20,000
Big Cow Creek Ditch Co.	701	1448	Shasta	Cow (Main) Creek	Agricultural	800		10.00		11,000
Jas. Wm. Schielke	706	1495	Trinity	New River	Mining			1.25		10,000
Hutchinson Co.	726	1444	San Joaquin	Stanislaus River	Agricultural	447		0.68		9,000
Matthew A. Little	731	1567	Stanislaus	Stanislaus River	Agricultural	296		0.66		12,000
Henry J. Barton	750	1625	Siskiyou	Beaver Creek	Mining			3.00		20,000

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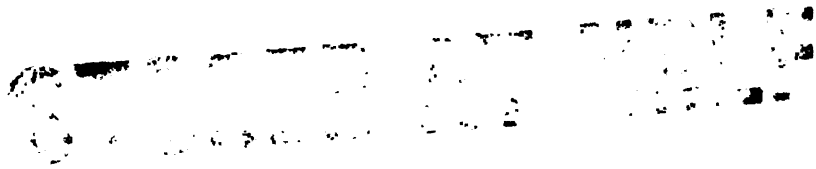
TABLE 8.

Relative Importance of Present and Proposed Power and Irrigation Development on Certain Important Streams of California.

(The data has been compiled from several sources and is approximate. Data as to proposed development is from records of State Water Commission except as noted).

River	Present power development			Proposed power development				Irrigation development		
	Number of important plants	Storage	Total theoretical horse-power	Number of important plants	Storage	Total theoretical horse-power	Cost	Present acreage	Proposed	
									Acreage	Cost
American	2	Yes	11,600	4	Yes	194,000	$9,570,000	13,400	2,000	$40,000
Feather	4	Yes	92,200	2	Yes	138,000	10,500,000	82,000	335,000	7,620,000
				*6	Yes	585,000	76,000,000			
Kaweah	3	Yes	9,200	----	----	----	----	100,000	61,000	1,520,000
Kern	3	No	44,200	5	Yes	267,000	23,620,000	180,000	225,000	15,000,000
				*2	----	80,000	8,000,000			
Kings	----	----	----	11	Yes	908,000	107,500,000	600,000	600,000	30,000,000
Klamath	7	Yes	25,500	2	Yes	336,000	22,000,000	68,600	240,000	18,750,000
				*4	Yes	163,000	16,300,000			
Merced	2	No	1,100	4	Yes	211,000	19,430,000	45,000	294,000	15,225,000
Mokelumne	1	Yes	26,800	3	Yes	39,000	1,940,000	13,000	395,000	10,117,000
Owens	6	Yes	35,600	7	Yes	152,000	13,258,000	125,000	----	----
				*1	No	12,000	*1,250,000			
Sacramento and upper tributaries	11	Yes	74,200	9	Yes	415,000	41,300,000	312,500	873,000	51,540,000
				*6	No	456,000	45,600,000			
San Joaquin	8	Yes	164,100	14	Yes	1,808,000	204,000,000	600,000	665,000	23,252,000
Stanislaus	4	Yes	52,100	4	Yes	121,000	4,160,000	76,000	174,000	3,350,000
Tuolumne	2	Yes	5,200	7	Yes	370,000	33,970,000	170,000	146,000	4,650,000
				*6	Yes	244,000	24,400,000			
Yuba	7	Yes	101,100	9	Yes	243,000	24,000,000	34,500	265,000	6,800,000
				*1	Yes	67,000	6,700,000			
Totals	60		642,900	81		5,195,000	$515,248,000	2,415,000	4,275,000	$187,864,000
				*26		*1,607,000	*178,250,000			
	60		642,900	107		6,802,000	$693,498,000	2,415,000	4,275,000	$187,864,000

*Proposed power plants for which applications have not been filed with the State Water Commission.



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